SEDGWICK'S PRINCIPLES OF SANITARY SCIENCE AND PUBLIC HEALTH

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SEDGWICK'S PRINCIPLES OF SANITARY SCIENCE AND PUBLIC HEALTH

REWRITTEN AND ENLARGED

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PREFACE

For more than a decade before the beginning of the twentieth century Professor Sedgwick had taken a leading part, both as an inspiring teacher and a clear-visioned investigator, in promoting the great sanitary awakening which occurred in America subsequent to 1890. With keen perception he foresaw the vast significance of the new science of bacteriology and the applications of the principles of physiology to hygienic living, and visualized the coming expansion of those varied activities destined to find their application in the promotion of the Public Health, and became one of its foremost apostles. His compelling interest and wide reading in this field found crystallized expression in his stimulating book, *The Principles of Sanitary Science and the Public Health,* which appeared in 1901. By its lucidity and beauty of expression, and its emphasis on the great achievements of bacteriology in relation to sanitation and the health of the community, the book not only was an authoritative source of information for students and public health officials, but became a classic in the literature of Sanitary Science.

Since the date of its publication great forward strides have been made in public health practice and in the fundamental sciences on which it is based. Furthermore, large foundations interested in promoting the public health have been organized; great national health agencies have come into being; and public health has become a matter of national and even of international concern. Today instruction in hygiene, often involving both personal and community health, is a part of the educational program in many elementary and high schools, and nearly always, in some form, in every college and university. In a more popular manner, the daily press and the weekly and monthly periodicals often carry articles of public health interest, and the radio, motion picture, exhibits, and other devices for disseminating information are often utilized in the program of popular enlightenment in matters pertaining to personal and public health. In many localities these efforts have been supplemented by the friendly and informative visits of public health nurses in the home and by the

publication and general distribution of leaflets, pamphlets, and other printed literature on matters pertaining to personal and public health by city, state, Federal, and voluntary health agencies. In short, public health has developed in less than two generations from an embryonic science into an active profession. The concentration of the population in large urban centers, and the development of rapid means of communication and transportation, have accentuated the need of progressive public health practice. The future is likely to see even greater emphasis on health conservation and public health protection. The safeguards of sanitary science must be made secure if people are to continue to enjoy its benefits to life and health, and as the first stages in sanitary development are universally achieved, further developments will doubtless occur to insure even greater health protection and comfort to the people.

In the light of the many and important advances which have been made in sanitary science since the publication of Professor Sedgwick's classic work, and in view of its great popularity, the publishers requested the authors to rewrite and enlarge Professor Sedgwick's book and to present the modern concepts of Sanitary Science. Since both authors had the privilege of studying with Professor Sedgwick and of serving later as his colleagues, the work has been done in a great measure as a tribute to a revered master. Any attempt to emulate his style of writing or to copy his unusual and graphic method of expression, would be presumptuous and probably unsuccessful. Nevertheless an effort has been made to present a view of modern sanitary science in a form which will appeal to the intelligent and interested general reader, as well as to those in or entering upon the public health profession.

The chapters on Health, Old Age, and Disease; Sewage and Excreta as Vehicles of Disease and Their Proper Disposal; on Water as a Vehicle of Infectious Disease; on the Protection and Purification of Public Water Supplies; on Ice as a Vehicle of Disease; on Certain Uncooked Foods as Vehicles of Disease; on the Prevention and Inhibition of Infection, Decomposition, and Decay; and on the Destruction or Removal of Infection, have been largely rewritten. Somewhat less change has been made in the chapters on the Etiology of Disease; the Rise and Influence of Bacteriology; Sanitary Aspects of the Struggle for Existence; Infection and Contagion: the Paths and Portals by Which They Enter the

Body; and Dirt, Dust, Air, and Disease. In order to present what we believe to be a reasonably complete and well-rounded view of modern Sanitary Science fourteen entirely new chapters have been prepared to cover subjects not included in the original text, or chapters which have become obsolete.

While the preparation of this text has been designed primarily for students in science or engineering interested in sanitary science and public health, it is hoped that the subject matter included in the revision may have a more widespread appeal. It should also prove of interest and value to public health officials, public health engineers, public health nurses, social workers, and civic-minded men and women who are interested in public health work.

The authors are indebted to Professor J. W. M. Bunker and Mr. Robert S. Harris for carefully scrutinizing the chapter on Nutrition and the Public Health; to Dr. George H. Bigelow and Dr. Herbert L. Lombard for critical reading of the chapter on Public Health Aspects of Chronic Disease; and to Mrs. Louise Peirce Horwood who read the entire manuscript and who made numerous suggestions for changes which were adopted.

Samuel C. Prescott
Murray P. Horwood

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SANITARY SCIENCE AND PUBLIC HEALTH

PRINCIPLES OF SANITARY SCIENCE AND PUBLIC HEALTH

CHAPTER I

HEALTH, OLD AGE, AND DISEASE

The human mechanism. — We must endeavor to obtain at the outset clear ideas of what is meant by the words "health" and "disease," which, to physiologists at least, are terms of precise and definite meaning indicating actual states or conditions of the living body. A moment's consideration will show that it is essentially no more difficult to comprehend the idea of a general state or condition of a living body than a general state or condition of a lifeless body, such as a stone or a piece of iron or a watch or a locomotive.

Closely examined, the living body reveals itself as a machine or mechanism composed of parts (called organs) precisely as a watch does. Very much in the same sense that a watch is a time-piece a living body is a life-piece. If a watch appears to be in good order and running well, we say that it is a good and normal time-piece. So also if the human body appears to be in good order and working well, we call it a normal or healthy body; but if it be out of order and not working well, we say that it is in a state of "disease," either temporary or permanent. In a word, health is the normal, and disease the abnormal, condition of the living mechanism. Nor is this a mere analogy or abstraction. To the biologist it calls up a picture — the picture of health or the picture of disease. For precisely as the experienced watchmaker carries in his mind's eye and can at any moment summon up a mental image of intricate, correlated, and interdependent parts — springs, wheels, bearings — lying concealed within, but which, taken together and in a certain definite and orderly relation one to another, make up the works of a delicately adjusted chronometer in actual operation, and constitute a valuable time-keeper, so the physiologist, familiar with bones, muscles, and nerves, with good red blood and beating heart,

all coöperating to a common end — the healthy, normal life of the organism — can summon up at will the picture of normal, vigorous, almost superfluous vitality in some vascular life-keeper. And in one sense, hardly more wonderful to him is the pulsing, vibrant, living mechanism than to the jeweler the accurate chronometer of delicate adjustment. To the savage the watch would be incomprehensible and inexplicable. And so to others than physiologists the living body seems something altogether strange and wholly apart.

The student of sanitary science must take up the physiologist's point of view. He must look upon the living body as a mechanism; a mechanism of curious origin and history and of marvelous complexity; the most wonderful of all machines; one before which the wisest of men stands very much as does the savage before the chronometer, ignorant of its origin, ignorant of its ultimate construction, ignorant of its fate; but yet unlike the savage because without superstition and without fear; knowing that the body is nevertheless a mechanism, subject to natural laws, and with all its parts coöperating to one end — the life-keeping function of the whole. The living body is like a machine, also, in that it receives all its energy from without and is merely a transformer of energy; in that it is profoundly sensitive (as is a watch) to its environment — to heat, to cold, to mechanical injuries. This living machine may be well built or ill; of good timber or poor; it may be sound and flawless or defective in construction. These are accidents of birth or ancestry; effects of good feeding or bad, of normal living or abnormal.

The making of the body. Youth and maturity. — Unlike the watch, the living mechanism is not made, but grows. With the fusion of two unlike cells — ovum and spermatozoön — the life of the individual begins. Henceforward its increase in size, its acquirement of organs and tissues, its powers and properties, are due, not as in the making of a watch to the assembling and coöperation of parts already perfected, but to processes of its own, to cell growth, cell multiplication, cell differentiation — balanced, adjusted, directed, and controlled chiefly from within. The first portion of this development takes place within the body of the parent, and is called intra-uterine or *embryonic life;* the second is a helpless state outside the body, but under parental care, the period of *infancy;* a third, somewhat less dependent but ill-defined, is the period of childhood and adolescence. These three periods — the periods of youth — ripen into adult life or maturity, and this

passes on into old age. Only very rarely does the mechanism last longer than a century. Usually, long before this it has stopped in death, which may have marked the end of life at birth, or even long before it, in infancy, in childhood, in maturity, or in age. The period of growth and the period of decline — infancy and old age — appear to be the periods when death is least successfully resisted. As has been finely said: "In this last respect the two extremes of life resemble one another. The freshly lighted taper and that which is burnt down to the socket are both easily extinguished by the slightest puff of wind." *

Old age. — Finally the living mechanism may wear out — it must wear out. No machine, however perfect, can run or be run forever. However smooth its bearings, however perfect its adjustments, dust and friction, and wear and tear, do their work, and in time the machine becomes old. So, also, is it with the human mechanism No matter how well cared for, or how cleverly managed, old age finally creeps over it; the rust of rheumatism gathers in its joints; its bearings grow eccentric; its movements irregular and halting; until by and by something breaks, and death stops the whole machinery. Death is the final stoppage of the living mechanism. But while theoretically this comes only when all parts are worn out, and as the simple, natural cessation of function from sheer and general debility of each and every organ, it does not in fact come very often in this way. The machine breaks down; it does not wear out. Some organ or part gives out comparatively early, and by failure to do its part destroys the whole.

Facts like these may or may not have inspired the author of the "One-Hoss Shay," who, in his famous poem has described the building of the body; its defects of constitution and construction; the ordinary causes of its death; and, finally, the theoretic possibility of so making a living body that it shall die at last only because it is worn out, namely, from old age. In the person of the deacon the Autocrat, himself a physiologist, has, consciously or unconsciously, stated the case as follows:

> "Now in building of chaises, I tell you what,
> There is always *somewhere* a weakest spot, —
> In hub, tire, felloe, in spring or thill,
> In panel, or cross-bar, or floor, or sill,

* P. H. Pye-Smith, *Lumleian Lectures*, London, 1892.

In screw, bolt, thoroughbrace, — lurking still,
Find it somewhere you must and will, —
Above or below, or within or without, —
And that's the reason, beyond a doubt,
A chaise *breaks down*, but doesn't *wear out.*"

His remedy for this unfortunate state of things was, —

"only jest
T' make that place uz strong uz the rest."

Accordingly the deacon proceeded to build his masterpiece in such a way that —

"The wheels were just as strong as the thills,
And the floor was just as strong as the sills,
And the panels just as strong as the floor,
And the whippletree neither less nor more,
And the back cross-bar as strong as the fore,
And spring, and axle and hub *encore*," —

with the result that after a whole century of life though there were indeed

. . . "traces of age in the one-hoss shay,
A general flavor of mild decay,"

there was

"nothing local as one may say!"

And when the end came from sheer old age,

. . . "it went to pieces all at once —
All at once, and nothing first —
Just as bubbles do when they burst."

Such is old age: the low-burning flame, which flickers and finally goes out; the ripened fruit, which drops heavily to earth; the old mechanism, which after long years of service finally refuses to work, simply because it is worn out. All this is the natural and ordinary course of life. With this sanitary science has but little to do except to exercise a wholesome supervision and watchfulness and to provide the most favorable environment possible. With ordinary breakdowns from defects in the machine itself, in its construction, or its operation, sanitary science has also little if anything to do. Good stock comes by inheritance not by manufacture, as truly in men as in timber. Men do not gather grapes from thorns or figs from thistles. Neither do strong constitutions, as a rule, spring from weak ancestors or good lungs from tuberculous parentage.

Death and its causes. — Life is the period of activity of the vital mechanism. Death marks the final stoppage of that machinery. Life is a perpetual struggle of the organism with its environment. Death marks its final and unconditional surrender. In the higher forms of life death is the natural and inevitable end of life. Old age marks the approach of death and is not less natural and inevitable. Doubtless the principal cause of death should be old age, the natural maturity of the organism, the gradual and irreparable wearing out of the vital machinery. Yet if we turn to any work on vital statistics, we find far more prominence given to other factors of mortality. In the enumeration of the causes of death in the U.S. Mortality Registration Area, where the International List of Causes of Death is employed, there are found exactly 200 causes of death distributed among 18 general classes. These are shown in the following table giving the deaths that occurred in the United States in 1933.

TABLE 1

CAUSES OF DEATH IN THE UNITED STATES, 1933 *

Class	Deaths	Per Cent
1. Infectious and parasitic diseases	155,813	11.6
2. Cancers and other tumors	134,535	10.0
3. Rheumatic diseases, nutritional diseases, diseases of the endocrine gland, and other general diseases	41,614	3.1
4. Diseases of the blood and blood making organs	10,186	0.76
5. Chronic poisonings and intoxications	3,561	0.27
6. Diseases of the nervous system and of the organs of special sense	130,957	9.75
7. Diseases of the circulatory system	314,000	23.4
8. Diseases of the respiratory system	100,546	7.5
9. Diseases of the digestive system	92,570	6.9
10. Diseases of the genito-urinary system	121,571	9.1
11. Diseases of pregnancy, childbirth, and the puerperal state	12,884	0.96
12. Diseases of the skin and cellular tissue	2,133	0.16
13. Diseases of the bones and organs of locomotion	1,596	0.12
14. Congenital malformations	12,112	0.90
15. Diseases of early infancy	51,450	3.84
16. Senility	11,318	0.84
17. Violent and accidental deaths	123,201	9.2
18. Ill-defined causes of death	22,036	1.6
Total	1,342,073	100.0

* *U. S. Public Health Reports*, v. 49, No. 42, Oct. 19, 1934, p. 1242.

The picture presented by a typical mortality table today is quite different from that which was common 50 to 60 years ago, at the dawn of the modern era of sanitary science. At that time communicable diseases took a tremendous toll in human life annually, the mortality from tuberculosis, diphtheria, scarlet fever, typhoid fever, diarrhea and enteritis, etc., being far in excess of the toll claimed by these same diseases today. In 1930, there were 49,503 deaths in Massachusetts, only 4,395 more deaths than occurred in the same state in 1890, although the population increased from 2,238,947 in 1890 to 4,249,614 in 1930. Comparatively speaking, old age was a rare attainment. Accordingly, people did not live long enough to enter those age groups where the so-called degenerative diseases — organic heart disease, cancer, nephritis arteriosclerosis, etc. — became significant factors as causes of death. Today, however, these and other constitutional degenerations, together with deaths resulting from accidents, represent by far the most important causes of death. The infectious and parasitic diseases have been largely brought under control, and in 1930, were responsible for only 8.5 per cent of the total deaths occurring in Massachusetts and in 1933, for 11.6 per cent of the total deaths that occurred in the United States.

While this is true on the basis of the classification of causes of death in use today, it must be remembered that there are many deaths which are attributed to constitutional or organic defects, which are essentially due to bacterial infections and should therefore rightly be classified with the infectious and parasitic diseases. For example, infections of the ear and of the mastoid process, infections of the heart, bronchitis, broncho-pneumonia, lobar pneumonia, pleurisy, intestinal ulcers, diarrhea and enteritis, puerperal septicemia, and rheumatic diseases, all of which are responsible for many deaths annually, are not classified with the infectious and parasitic diseases like diphtheria, typhoid fever, tuberculosis, and malaria. It is fair to say that if they were, the group known as infectious and parasitic diseases, would still represent the most important single cause of death, even today.

Disease, not old age, the principal agent of death. — One conclusion that stands out clearly in the preceding table is that old age or senility, which may be considered the most natural cause of death, is comparatively rare, being responsible for only 68 deaths in Massachusetts in 1930, or approximately 0.1 per cent

of all the deaths occurring in that state. Many deaths formerly attributed to old age are now diagnosed more satisfactorily, and are assigned to other causes.

A better estimate of the changing status of certain important causes of death may be obtained from the data presented in the following table. While the comparison is only between the first and sixth five-year periods of the twentieth century and not between 1880–1884 and 1925–1929, the periods covered are sufficiently far apart in the modern public health movement to yield

TABLE 2

AVERAGE ANNUAL DEATH RATES PER 100,000 FOR LEADING CAUSES OF DEATH, 1900–1904, AND 1925–1929, BASED ON THE TOTAL POPULATION IN THE ORIGINAL REGISTRATION STATES *

CAUSE OF DEATH AND RANK, 1900–1904	ANNUAL AVERAGE DEATH RATES 1900–1904	ANNUAL AVERAGE DEATH RATES 1925–1929	CAUSE OF DEATH AND RANK, 1925–1929	ANNUAL AVERAGE DEATH RATES 1925–1929
1. Tuberculosis—all forms	184.7	77.2	1. Organic heart disease [2]	219.7
2. Pneumonia—all forms	161.5	103.1	2. Cancer	114.3
3. Heart disease [2]	127.7	219.7	3. Pneumonia—all forms	103.1
4. Nephritis [3]	93.6	46.6	4. Nephritis [3]	96.6
5. Diarrhea and enteritis under 2 years	91.4 [1]	18.0	5. Apoplexy	88.3
6. Apoplexy	75.6	88.3	6. Tuberculosis—all forms	77.2
7. Cancer	67.5	114.3	7. Premature birth	33.4
8. Ill-defined causes	48.4	2.4	8. Influenza	25.1
9. Old age	45.1	6.5	9. Diabetes mellitus	22.6
10. Bronchitis [3]	39.3	7.7	10. Automobile accidents [6]	21.5
11. Meningitis [4]	33.1	5.6	11. Angina pectoris	19.6
12. Diphtheria	32.8	7.6	12. Diarrhea and enteritis under 2 years	18.0
13. Premature birth	32.6	33.4	13. Accidental falls	16.5
14. Typhoid fever	26.8	2.4	14. Appendicitis	15.2
15. Influenza	22.9	25.1	15. Suicides	14.2
16. Paralysis [5]	22.5	3.0	16. Congenital malformations	14.0
17. Congenital debility	21.8 [1]	5.4	17. The puerperal state	12.1
18. Convulsions	19.8	1.1	18. Hernia, intestinal obstruction	10.8
19. "Other diseases of the stomach"	19.5		19. Bronchitis [3]	7.7
20. Lack of care	15.1 [1]	0.1	20. Diphtheria	7.6

[1] Death rate in Registration Area

[2] Excluding pericarditis, acute endocarditis, acute myocarditis and angina pectoris.

[3] Acute and chronic.

[4] Including epidemic cerebrospinal form.

[5] Without specified cause

[6] Excludes deaths in collisions of automobiles with railroad trains or street cars.

* *Statistical Bulletin*, Metropolitan Life Insurance Company, v. xiii, No. 4 April, 1932.

significant results. It is not necessary to analyze in detail the data presented here, but it will be clear even to the casual observer, that the so-called degenerative or constitutional diseases as well as the deaths due to accidents are far more important today than they were even a generation ago. It should be remembered, however, as was pointed out above, that many of the deaths assigned to the degenerative diseases today are in reality the result of microbic infections and are not simply the result of the wearing out of the human mechanism. Theoretically, these deaths should be preventable. Hence, the emphasis which is being placed on the necessity of a thorough, annual medical examination in order that serious constitutional defects may be detected early, and the necessary corrective measures taken in time. Old age, or the gradual disintegration of the human machine, is, in reality, only an infrequent cause of death, even today.

Another classification of the causes of death. — A simpler, and for our purpose more helpful, view of the causes of death is one which seeks to classify them roughly according to their apparent place of origin, simply regarding them as either —

(*a*) *Intrinsic* causes, or arising within the body proper, or

(*b*) *Extrinsic* causes, arising outside the body or acting upon it from without.

From this standpoint diseases may be regarded as due either to defects in the constitution or construction of the vital mechanism, or else to external unfavorable influences acting upon it. From the point of view of origin or causation, all diseases may be divided into two classes, viz.: (1) *Constitutional*, or (2) *Environmental.*

This classification, while open to many objections, is of the highest value to the physiologist and the sanitarian, for it brings the former face to face with intrinsic, structural, or organic defects in the mechanism, while the attention of the latter is concentrated upon those abnormal external influences which act unfavorably upon the organism, and which he must seek, and may be able, to remove. It will be found instructive to carry this line of thought into the following sections, carefully keeping in mind the fact that many so-called intrinsic causes probably have in reality an extrinsic source or origin.

Intrinsic or structural defects of the vital machinery; constitutional diseases. — The human body is a wonderful machine, an admirable piece of mechanism. Like other complicated machines,

it has a definite structure and interdependent and reciprocating parts. These are naturally adjusted to the performance of certain duties or functions, and a failure of one part may involve the failure of all other parts and thus of the entire vital apparatus. If, for example, the heart is defective and fails to do its duty, the circulation is affected unfavorably and the whole body suffers. It needs no further argument or illustration to show that a structural flaw or defect in the living machine may mean disaster and death, however favorable all external conditions may be. A condition of the blood, or a roughness upon the valves of the heart, which shall produce a clot, or a weakening of an arterial wall in the brain which shall finally produce cerebral hemorrhage or cause apoplexy, is an intrinsic or structural defect which may not be directly attributable to any unfavorable external condition. It may be a flaw in the machine, an intrinsic and perhaps inherited defect of structure, and, if so, it is remediable only by fundamental changes in organization which sanitary science cannot hope to establish, unless after many generations and by steps which are at present quite beyond its reach. Diseases of this class are diseases of construction, *i.e.*, "intrinsic" or "constitutional." They belong as yet in the field of the biologist, the physiologist, and the hygienist rather than that of the sanitarian; to personal hygiene, rather than public health or sanitation.

Extrinsic or external interferences with the vital machinery; environmental diseases. — The human body is subject — sensitive, even — to external conditions: cold or heat, fire or water, may so act upon the human body as to produce death by freezing, burning, or drowning. Forces, such as gravity or electricity, may be causes of death by falling, crushing, or execution. These and similar causes are clearly extrinsic or environmental, and come under the head of accident or violence — unless we except suicide as perhaps due to constitutional peculiarities. Some diseases have already been spoken of as constitutional or intrinsic, but many diseases do not come under this head. The common expression which describes a communicable disease like diphtheria, scarlet fever, or typhoid fever as an "attack" is noteworthy as indicating the popular recognition of the fact that disease often has its source outside of the body. It is now believed that many diseases originate exclusively from unfavorable environmental influences, and since the celebrated discovery of 1839 of the vegetable nature of the

cause of *favus* (honeycomb of the scalp), it has been found that not a few diseases are due to parasites, which invade the organism and interfere with its normal working.

The prevention of constitutional diseases the special function of personal hygiene. — If diseases due to defects or flaws in the vital machinery are to be avoided, this is obviously to be done only by improving and perfecting the apparatus, which is a comparatively slow and difficult matter. To make a family of weak constitution strong, is to reconstitute its entire physical basis; and if this can be done at all, it may be only after generations shall have come and gone. It must be done by careful living and good feeding, wise intermarriage, and severe natural selection. To ward off adventitious disease is, in these cases, not enough. The whole structure must be made over. Sanitation alone cannot hope to effect these changes. They must come from scientific hygiene carefully applied throughout long generations.

Extrinsic or environmental diseases mainly preventable and therefore within the scope of sanitation. — Diseases which arise from some invasion of the organism may possibly be warded off. As they virtually proceed from the environment which, in theory at least, is under our control, they may be prevented. With such diseases the sanitary science of today is chiefly concerned. Sanitation has virtually stamped out typhoid fever in many civilized communities, and smallpox has been eliminated wherever vaccination is practised universally. Diphtheria and scarlet fever have also been brought under control; tuberculosis mortality has been greatly diminished; malaria, yellow fever, hookworm, typhus fever, and plague have ceased to be devastating epidemic afflictions wherever the necessary environmental control has been introduced effectively. There can be no question that sanitary science has already won signal victories, and that its practitioners may reasonably hope for fresh laurels in the future. Witness, for example, the remarkable reduction in infant and child mortality during the first third of the twentieth century, accomplished largely through the improvement and pasteurization of milk supplies, the improvement in infant feeding, and the advance in our knowledge of the requirements of healthy living.

On the other hand, there is a group of communicable diseases, the control of which does not depend fundamentally on environmental factors, in which little or no progress has been made. The

common cold, one of the most widespread of all human afflictions, is still prevalent without any abatement in all of our communities during the cooler months of the year. Influenza and pneumonia, such devastating diseases at times, have not yet been brought under control. In fact, we do not even know yet the causative agent of influenza, although a great deal of work has been done in an effort to obtain this information. Measles, too, one of the commonest diseases of the race, is still of unknown etiology, and until recently, no effective preventive or specific treatment was available other than good nursing care and the constitutional resistance of the patient. Similarly, the control of the venereal diseases, which is dependent on the control of the individual and not his environment, has been unsuccessful, and these social diseases are prevalent today virtually without abatement. It is comparatively easy to control the environment in most instances. It is much more difficult to control the actions and movements of men and women in a free society. Hence sanitary science has been more successful in controlling the environmental diseases than it has those which are linked up with individual behavior.

The prevention of premature death, the principal function of hygiene and sanitation. — From what has been said above it would appear that disease is the principal agent of death. But it must be kept in mind that disease (except in infants) is often facilitated in its work by age or enfeeblement, which gives it a foothold and incapacitates the organism for resisting its activity. Physiologists and physicians recognize differences of condition in which the body seems to possess great powers of resistance or endurance, or only small powers. In this way it often happens that a structural or constitutional enfeeblement exposes the organism to the invasion of environmental disease.

A little reflection will show that death, as a rule, comes prematurely. Old age, the only theoretically normal and natural cause of death, is very rarely the one and only cause. Poor timber or poor materials or poor construction of the living machinery, alone or together making up a poor "constitution," or else violence, poison, parasites, or other unfavorable elements in the environment, usually bring on disease and death long before the appointed threescore years and ten, or the rarer fourscore years. Some die before they are born; more before one year of life is over; others under five years, ten, or twenty. Some live on for

thirty, forty, or fifty years; but for the great majority death comes before old age. Some idea of the ages which people attain before death intervenes can be obtained from the following table which distributes the deaths occurring in Massachusetts in 1932 according to age groups.

TABLE 3

DEATHS OCCURRING IN MASSACHUSETTS IN 1932 DISTRIBUTED ACCORDING TO AGE

AGE GROUP	DEATHS	PER CENT	CUMULATIVE PER CENT
Under 1	3,635	7.3	7.3
1– 4	1,152	2.3	9.6
5– 9	573	1.2	10.8
10–14	506	1.0	11.8
15–19	662	1.3	13.1
20–29	1,850	3.7	16.8
30–39	2,648	5.3	22.1
40–49	4,220	8.5	30.6
50–59	7,181	14.5	45.1
60–69	10,358	21.0	66.1
70–79	10,475	21.2	87.3
80–89	5,376	10.9	98.2
90–99	875	1.8	100.0
100 and over	20	0.0	100.0
Total	49,531	100 0	100.0

Shakespeare, in the graphic words of Jaques in *As You Like It* (Act II, Scene VII), presents the understanding view that life is composed of different age groups, with their different interests, hazards, and changes in physical vigor or vitality!

"All the world's a stage,
And all the men and women merely players:
They have their exits and their entrances;
And each man in his time plays many parts,
His acts being seven ages. At first the infant,
Mewling and puking in the nurse's arms;
Then the whining school-boy, with his satchel
And shining morning face, creeping like snail
Unwillingly to school; and then the lover,
Sighing like furnace, with a woeful ballad
Made to his mistress' eyebrow; then a soldier,
Full of strange oaths and bearded like the pard,
Jealous in honour, sudden and quick in quarrel,
Seeking the bubble reputation
Even in the canon's mouth; and then the justice,

In fair round belly with good capon lin'd,
With eyes severe and beard of formal cut,
Full of wise saws and modern instances;
And so he plays his part, the sixth age shifts
Into the lean and slipper'd pantaloon,
With spectacles on nose and pouch on side,
His youthful hose well sav'd, a world too wide
For his shrunk shank; and his big manly voice,
Turning again toward childish treble, pipes
And whistles in his sound, last scene of all,
That ends this strange eventful history,
Is second childishness and mere oblivion,
Sans teeth, sans eyes, sans taste, sans everything."

Hygiene and sanitary science. — Sanitary science is the science of health. It is commonly held to be, and commonly it is, much the same thing as hygiene. Sciences and arts, however, like living organisms, grow, differentiate and divide, and hygiene is no exception to the rule. The wonderful developments which have taken place within the last half century in our knowledge of the causes of disease, and especially those diseases proceeding from the environment, together with the corresponding advancement in our arts for their prevention or control — the sanitary arts — have brought about a differentiation of hygiene such that one portion of it now deals naturally and mainly with the environment of man, while another portion deals naturally and mainly with man himself.

As the environment is usually shared in common by many persons, that branch of hygiene which deals mainly with the environment may conveniently be called "public" hygiene; while the remainder, dealing as it does chiefly with the individual, may properly be designated "personal" hygiene. Underlying both personal and public hygiene there are certain fundamental principles of the causation and prevention of disease which are absolutely essential to all sound practice of the sanitary arts. These, steadily growing in number and importance as the years go by, constitute the firm foundation on which both the theory and the practice of personal and public hygiene rest. Moreover, because they are founded largely upon experiment, and are in harmony with established laws of nature, they may be said to constitute the beginnings, at least, of a sanitary "science." Furthermore, inasmuch as the environment is not only more accessible for treatment than the individual, but also far more under our influence and

control, it has naturally come to pass that sanitary science consists very largely of principles derived from, and applicable to, problems relating to the environment rather than the individual. Hence it happens that it is at present most often and most naturally associated with public hygiene or the public health rather than with general hygiene or with personal hygiene, or the health of the individual.

The whole subject of proper food and clothing, for example, pertains to general or personal hygiene; but sanitary science is more especially concerned with infected food and the control of the environment in general for the health, comfort, and convenience of man. Whether the citizens of Boston or Paris dress warmly enough, or too warmly; whether cotton, linen, or wool is, on the whole, the most suitable for the climate of New York or London at all seasons or at any season — these are questions of personal hygiene; but to sanitary science and the public health belong questions of polluted water, polluted milk, and polluted air; questions concerning the origin, dangers, and disposal of sewage; questions concerning the transmission of disease through flies, mosquitoes, and rodents; questions of heating and ventilation; of sunlight and smoke; of obnoxious gases and vapors; questions of noise and dangerous trades; and questions relating to dust and disease and to the natural history of epidemics. The practice of sanitary science is founded, as applied science must always be founded, upon a basis of established truth. Upon this sure basis we may construct a framework of philosophical explanation, or theory, by the aid of which we may hope to make or measure new discoveries. Though often unrecognized, some such working theory lies at the bottom of all sanitary endeavor. It has underlain the prayers and incantations of savages; it underlies all quarantine regulations; it is at the foundation of all sanitary authority.

The past eighty years have witnessed vast additions to our store of established truth, and vast changes in our stock of theory, underlying all the application of sanitary science. These additions we owe almost wholly to one simple mechanical discovery in the domain of physics — the discovery how to make an achromatic microscope objective. This discovery so facilitated and stimulated the use of the microscope that it has revolutionized ideas of the causation of disease; has established physiology upon a broad and firm foundation; and has created new sciences of immense impor-

tance, such as bacteriology, pathology, and parasitology, from which has resulted the great progress in preventive medicine and public health.

Definitions. — From the foregoing it is clear that there are several aspects of sanitary science, one dealing primarily with individual behavior, and another, essentially with the effect of the environment on the individual. The first is called personal hygiene, and the second, sanitation. To a consideration of these and certain allied definitions we may now logically turn, always remembering, however, that definitions are only approximately correct and must not be taken too literally.

Personal hygiene is the science and art of the conservation and promotion of personal health. It includes especially problems relating to nutrition and the satisfactory feeding of the individual, to his personal cleanliness, his sleep and rest, his work and fatigue, his mental joy and happiness and absence of worry, his muscular exercise, the use of stimulants and narcotics, the clothing he wears on all occasions, and the care of the eyes, the ears, the teeth, the mouth, the bowels, the hair, and other organs. Certain practices, however, such as vaccination against smallpox, immunization against typhoid fever or diphtheria, and the use of biological products in general, either for the preventive or curative treatment of disease, and which are properly within the domain of preventive medicine may be considered part of personal hygiene, since they deal with the treatment of individuals rather than the control of the environment.

Sanitation is the science and art of the conservation and promotion of the public health through the control of the environment. It has for its object the promotion of the health, comfort, and convenience of communities. Accordingly, it deals with those health problems that are common to groups or communities, such as water supplies, sewerage and drainage, refuse collection and disposal, milk supplies, food supplies, restaurant and food store sanitation, ice supplies, air conditioning, lighting, school sanitation, factory sanitation, housing, camp sanitation, roadside sanitation, sanitation of swimming pools, sanitary drinking facilities, street cleaning, parks and playgrounds, and the control of insects, rodents, odors, noises, obnoxious gases, and other nuisances or dangers to health.

There are two other terms which are used with great frequency by sanitarians or public health workers. One is preventive med-

icine, and the other public health. From the individual standpoint, preventive medicine is closely related to and largely synonymous with personal hygiene, with the use of biologic products for the prevention of disease and with the prompt and early treatment of disease before irreparable damage has been done. Public health is a broader term than either personal hygiene or sanitation. In fact it includes both. In addition it includes administrative practices such as analyses of vital statistics, epidemiological studies and investigations, sanitary inspections, public health education, public health laboratory service, the maintenance of clinics, sanatoria and hospitals, and other activities which cannot logically be classified under personal hygiene or sanitation.

Sanitary science, still another term that is used, should be regarded as the embodiment of those *principles* which help us to understand the sources of infection and modes of transmission of disease. Sanitary science draws on such allied sciences as physics, chemistry, and biology, and especially, bacteriology, parasitology, immunology, and epidemiology, as well as their engineering applications. By understanding and applying the principles of sanitary science the health of the individual and the health of the community may be safeguarded and promoted.

CHAPTER II

THE ETIOLOGY OR THE CAUSES OF DISEASE. ANCIENT AND MODERN THEORIES

The demonic theory of disease. — The earliest theories of disease with which we are acquainted are found among savage races, which naturally interpret fever, sickness, pain, madness, and hysteria as due to the temporary or prolonged occupancy of the affected body by an evil spirit or demon. This is called the *Demonic Theory*. The same subjective, anthropomorphic method of thought which sees in the sun, not a huge sphere of burning matter giving light and life to other worlds, but Apollo, a god, driving his chariot of fire daily across the sky; or fills the woods with fauns and satyrs, and the streams with nymphs and naiads, naturally looks for the causes of disease in human or inhuman forms distorted and misshapen according to the fancy, but gifted with human cunning and more than human malignity.*

The demonic theory regards disease as a supernatural being or entity, not primarily as a process or condition, and the diseased condition the result of the influence of some entity foreign to the patient, to something acting from or coming from the environment. Of any disease arising from within, or due to any intrinsic or mechanical defect or derangement of an apparatus — such as faulty materials or construction — the savage has no conception. This idea requires anatomical information and the power to reflect from the merely objective point of view; in other words, the modern mechanical and scientific attitude of mind, the objective rather than the subjective capacity. Even here, however, the cure was logically applied. Savage therapeutics accurately followed savage pathology. If the disease were due to the possession of the patient by a demon or demons, nothing could be more logical or better medical practice than to seek somehow to cast them out. Exhorta-

* For the substance, and to a great extent the form, of this entire section the authors are indebted to various writings of that eminent authority on primitive culture, Professor E. B. Tylor. His book on *Anthropology* contains a graphic account of historic attempts to exorcise demons from human beings as late as 1876.

tions, drums, or anything likely to influence the demon constituted a proper *materia medica.* Most effective of all would be the voice of a master who should command their obedience and compel them to come out.

It was even possible upon the demonic theory, crude and childish as it was, to have a legitimate "preventive medicine." "The very charms still exist by which the ancient Egyptians resisted the attacks of the wicked souls, who, become demons, entered the bodies of men to torment them with disease and drive them to furious madness." And we all know of survivals even today in the charms and amulets which are supposed to resist bad luck, and the more material horseshoe, rabbit's foot, horse chestnut in the trousers pocket, etc., which shall ward off witches or disease from us or from our habitations.

The theory of the four humors. — Long before the period of the highest development of Greek civilization, the primitive or demonic theory of disease had ceased to satisfy the minds of cultivated men. Many traces of it indeed remain in the Homeric time; but with the arrival of the age of Pericles we have as his contemporary Hippocrates, already called "the Great," and ever since known as the "Father of Medicine." And now, apparently, for the first time, we find "a clear recognition of disease as being equally with life a process governed by what we should now call natural laws. . . . The actual science of the Hippocratic school was of course very limited. In anatomy and physiology little advance has been made, and so of pathology in the sense of an explanation of morbid processes or knowledge of diseased structures there could be very little. . . . The dominating theory of disease was the humoral, which has never since ceased to influence medical thought and practice. According to this celebrated theory the body contains four humors — blood, phlegm, yellow bile, and black bile — a right proportion and mixture of which constitute health; improper proportion and irregular distribution, disease. It is doubtful whether the treatise in which this theory is fully expounded is as old as Hippocrates himself; but it was regarded as a Hippocratic doctrine, and when taken up and expanded by Galen, its terms not only became the common property of the profession, but passed into general literature and common language. Another Hippocratic doctrine, the influence of which is fortunately not even yet exhausted, is that of the healing power of

nature." * Much of the language of this famous theory still lingers, as when we speak of a "bilious" condition, a "sanguine," "phlegmatic," or "melancholic" (black bile) temperament. It had the high merit under Hippocrates of fixing attention upon natural rather than supernatural causes, upon the patient rather than demons.†

Roman, Arabian, and mediaeval theories of disease. — We need not follow in detail the shifting opinions of mankind as to the true causes of disease between the time of Hippocrates (500 B.C.) and that of Sydenham. In the decline of Greek culture and the Alexandrian period no new ideas of importance were successfully advanced or long maintained. The theory of the four humors, with various modifications and under various forms, prevailed, and even in the hands of Galen during the Roman period, though expanded and highly elaborated so that it became the standard authority for many centuries, remained essentially the same. During the Dark Ages no important new ideas were introduced into Europe by the Arabian physicians, Avicenna and Rhazes; for these authors worked largely upon the foundations laid by Hippocrates and Galen, and their theories need not detain us. The period of scholasticism also yielded nothing in the theory of disease beyond the four humors, but only endless commentaries on Hippocrates and Galen similar in character to those in philosophy upon Aristotle. Even for some time after the revival of learning and the splendid period of the Renaissance, this very revival being in the hands of "medical humanists" led to a renewed respect for ancient authority, and more than ever Hippocrates and Galen were regarded as authorities while the theory of the four humors naturally held full sway. With Paracelsus (1480–1541), however, emphatic doubts began to be boldly expressed as to the sufficiency of the ancient theories. The study of anatomy in Italy in the sixteenth century under Vesalius, Fallopius, Fabricus, and many others, followed as it was early in the seventeenth by Harvey's marvelous

* J. F. Payne, M.D., on the "History of Medicine," *Encyclopaedia Britannica*, 9th ed., v. XVII, p. 800.

† "The four Galenical humors, viz., the blood which took its origin in the liver, the phlegm secreted by the pituitary gland, the bile by the gall, and the black bile by the spleen. From the mixture of these humors arose the four natural 'temperaments': sanguine, in which the blood was predominant; phlegmatic or pituitous; bilious or choleric; atrabilious or melancholic; and from the ill-mixture of these ingredients resulted dyscrasia and new morbid humors, such as produced scurvy, scrofula and gout." — Pye-Smith.

discovery of the circulation of the blood, together with the general progress of knowledge, finally raised grave doubts in the best minds as to the true causes of disease, doubts which were powerfully supported by the occurrence in Europe in the fifteenth and sixteenth centuries of certain highly destructive epidemic diseases, some of them hitherto unknown and all quite inexplicable on the theory of the four humors. Meantime there arose two schools, called respectively the "iatro-physical" and "iatro-chemical," the former basing itself on physiology and mechanical explanations of disease, the latter on chemical or fermentative processes. "The intestine movement of particles," or "fermentation," was the essence of the latter, the application of physics and mechanics to the body that of the former. The name of Sylvius (1614–1672) is widely known in connection with the iatro-chemical school. These schools, however, were compelled to struggle not only each with the other but both with the ancient (Hippocratic) doctrines.

The seventeenth century theory of Sydenham. — Thomas Sydenham (1644–1689), who has been called "the English Hippocrates," held as "his main avowed principle to do without hypothesis and study the actual diseases in an unbiassed manner." According to Sydenham, "a disease is nothing more than an effort of nature to restore the health of the patient by the elimination of the morbific matter." This full recognition of a *materies morbi* was a distinct advance, and foreshadows the time when the *materies morbi* would itself be regarded as specific in specific diseases. Sydenham appears to have recognized the fact that there are specific diseases, but to have fixed his attention rather on specific remedies than specific causes. The latter were not fully recognized until after Pasteur's classic researches on the specific microbic ferments of the diseases of wine and beer (1860–1864). After Thomas Sydenham "the reign of canonical authority in medicine was at an end, though the dogmatic spirit long survived."

Theories of the eighteenth century. — The theories of disease in the eighteenth century reflect plainly the spirit of the times. On the one hand we find views largely mechanical, physical, and even astrological; and on the other, an opposing series more mystical, animistic, and even spiritualistic. As natural successors to Hippocrates, Galen, and Sydenham, we find Boerhaave, Haller, and Morgagni, while opposed to them and as natural successors to Paracelsus, Hoffmann, Stahl (author of the phlogiston theory) in

chemistry), and Hahnemann — all more or less supernaturalists. The labors of Boerhaave, Haller, and Morgagni served to establish upon a sure foundation our present essentially physical and mechanical views of constitutional disease, but shed very little light on the class of diseases now called "infections" (the fevers, etc.), which run a peculiar definite course and then disappear. But if these diseases baffled the naturalists of the eighteenth century, they were still less understood by the supernaturalists, of whom only one (Hahnemann) has succeeded in making himself felt in the nineteenth century by the perpetuation of a special "system" typical of the numerous "systems" of the eighteenth century.

The theory of Hahnemann. — "Hahnemann taught that disease is to be regarded as consisting especially of the symptoms of it as experienced and expressed by the patient, or as detected by the physician; in other words, that the chief symptoms, or the 'totality of the symptoms,' constitute the disease, and that disease is in no case caused by any material substance, but is only and always a peculiar, virtual, dynamic derangement of the health. 'Diseases' (Introduction to the *Organon*, p. 17) 'will not cease to be spiritual dynamic derangements of our spiritual vital principle.' He says on page 3 of the *Organon:* 'For as far as the greatest number of diseases are of dynamic (spiritual) nature, their cause is therefore not perceptible to the senses;' and at page 18, referring to 'small-pox, a disease accompanied by almost general suppuration,' he asks, 'Is it possible to entertain the idea of a material morbific matter being introduced into the blood?' He held that the psoric miasm, of which the itch is the outward and visible and comparatively harmless sign, was at the root of nearly all chronic disease, viz., of all chronic disease that was not due to syphilis or sycosis. . . . In all countries the doctrine of homoeopathy is still without broad scientific recognition. . . . Modern medicine is doing some of its best work in showing the material and the visible character of the causes of many of the commonest diseases, and suggests this in many cases where it has not as yet been demonstrated. The cause of many diseases is shown to be a living germ or particle which can be discerned under the microscope, can be carried on a lancet or in a tube and introduced into the body so as to produce its peculiar disease. . . . The causes of other diseases are often not merely visible under a microscope, but coarsely visible. . . . So with other forms of common disease

Alcohol does not destroy a liver or kidney in any dynamic or immaterial form, but in coarse quantities diligently repeated. The lead which paralyzes the painter's wrist is not a 'spiritual' thing. It is an accumulation of matter in the wrong place, and enters his body in palpable quantities, and, what is more, can be recovered in similar quantities from his body. . . . The itch, to whose mysterious workings Hahnemann attributed two-thirds of the internal diseases of the body, including mania, cancer, gout, etc., is easily demonstrated to be dependent on an ugly crab-like insect, which can be destroyed in a few hours with sulphur, when there is an end both of it and of the itch."

Theories of the nineteenth century. — If the eighteenth century is noteworthy for its numerous "systems" of medical theory, the nineteenth is equally conspicuous for its distrust of "systems." This was due doubtless in part to the natural swing of the pendulum, but whatever the cause may have been, there was unquestionably, in the first part of the century, a wholesome distrust of all "systems" and a return to a study of the "natural history of disease," what has been called a "rational empiricism" serving as the basis of medical practice. This "return to nature" was powerfully stimulated and facilitated by the rapid contemporary development of physical science, and above all by the invention of the achromatic microscope objective between 1815 and 1830, so that the compound microscope, which had been so imperfect as to be almost useless, became about 1835 a powerful and altogether novel instrument. Almost immediately results of capital importance were reached, for in 1837 an Italian investigator, Bassi, announced the discovery that *muscardine*, a contagious disease of silkworms, previously not understood, is really due to a parasitic fungus. Two years later the still more startling discovery was made by Schoenlein that *favus*, or "honeycomb" of the human scalp, a disease long known, but never understood, is really due to a parasitic fungus growing at the roots of the hair. At almost the same moment botanists discovered that yeast, hitherto regarded as a mysterious "ferment," is also a microscopic fungus; and the idea was boldly advanced that fermentation, which had long been held to be one of the causes of disease, was really due to microscopic fungi. The new microscope was also applied to the study of dis-

*J. Grey Glover, M.D., on "Homeopathy," *Encyclopedia Britannica*, 9th ed., v. XII, pp. 126–129.

eased tissue, and immediately disclosed ravages so coarse and obvious as to compel the idea of mechanical interference by palpable agents and to stimulate further search not only for the footprints of disease, but for the mysterious makers of those footprints. Meantime the applications of physics and chemistry to physiology by Johannes Muller and Wöhler, Marshall Hall and Liebig, were drawing attention to the mechanical and material aspects of living things and the modern conception of the body as a physical mechanism was becoming more firmly established. The pathologists likewise were making extraordinary progress in their explorations of the dead, and reporting constantly fresh examples of mechanical disturbance or interference, so that by the middle of the nineteenth century our theories of constitutional disease as largely due to poor timber or poor construction or mechanical breakdown were finally and probably forever established.

The case was different, however, with certain diseases, such as the fevers, which run a definite course and disappear. These remained still unexplained and inexplicable. But their solution also was at hand. The obscure phenomena of fermentation, as we have seen above, had been claimed to be closely connected with disease by the iatro-chemical school of the seventeenth century, and this suggestion had apparently never been wholly lost sight of, though it was eclipsed in the eighteenth century by the rapid development of physiology. Modern chemistry began to unfold itself toward the close of the eighteenth century, and by the end of the first half of the nineteenth century, when the achromatic objective had been perfected, fermentation had assumed in the hands of Liebig great popular importance.

The germ theory of fermentation. — Alcoholic fermentation had been generally regarded as a purely chemical or a physical process until in 1838 Cagniard de Latour and Schwann showed that the yeast which accompanies it is a living plant. Liebig met this discovery with scorn and ridiculed the idea that yeast was the cause rather than the consequence of fermentation in an article which Huxley has well called the most remarkable that ever appeared in a sober scientific journal. Nevertheless, though with many hindrances because of the powerful opposition of Liebig, it slowly became clear that the germ theory of fermentation is true, and that live yeast is the real "ferment" of the alcoholic fermen-

tation. This biological theory was thoroughly and finally established by Louis Pasteur between 1857 and 1863, and almost immediately led to the germ theory of disease through its extension by him to the diseases of beer and wine, which he traced to micro-organisms other than ordinary yeast invading the fermentable liquid and interfering with the usual alcoholic fermentation by producing undesirable fermentations of their own. At once it became clear to Pasteur (and soon after to the world) that specific fermentations are caused by specific ferments; and, moreover, that a disease of wine or beer may be, and often is, simply an undesirable fermentation produced by an invading ferment or germ.

The germ or zymotic (ferment) theory of disease. — It could hardly fail to occur to any thoughtful person that if this were true for certain diseases of wine and beer, it might well be true also for certain diseases of animals; * for if we consider step by step the course of any familiar fermentation and then do the same for any familiar infectious disease, we shall discover between them a remarkable similarity. For this purpose we may take the fermentation of apple juice, or cider, and smallpox. The juice of apples is hermetically sealed and kept from exposure to air by the apple skin. In the making of cider this skin is broken, the juice is pressed out and of course exposed to the air, to dust, to the press, to the sides of the vessel which receives it, to the strainer through which it passes, etc. At first, and for some time, the juice is sweet, insipid, unfermented, but after some time it is plain that a change is going on. This change is called the "working" or active fermentation of the apple juice, and a closer examination will show that it is accompanied by a slight rise of temperature or "heating" (which is a familiar phenomenon in many fermentations), as well as by obvious chemical changes resulting in the evolution of gas and the disappearance of sugar, in place of which alcohol makes its appear-

* "Les sciences gagnent toutes à se prêter un mutuel appui. Lorsque, à la suite de mes premières communications sur les fermentations, en 1857–1858, on put admettre que les ferments proprement dits sont des êtres vivants, que des germes d'organismes microscopiques abondent à la surface de tous les objets dans l'atmosphère et dans les eaux, que l'hypothèse d'une génération spontanée est présentment chimérique, que les vins, la bière, le vinaigre, le sang, l'urine, et tous les liquides de l'économie n'éprouvent aucune de leurs altérations communes au contact de l'air pur, la médecine et la chirurgie jetèrent les yeux sur ces clartés nouvelles. Un médecin français, le Dr. Davaine, fit la première application heureuse de ces principes à la médecine, en 1863." — Pasteur, *La Vie de Pasteur*, par René Vallery-Radot, Paris, 1900, p. 390.

ance giving to the whole process the name of "alcoholic fermentation." The fermentation of any particular portion of apple juice, however, is not indefinitely prolonged. On the contrary, after a comparatively short time the process comes to an end, the evolution of gas ceases, and rest supervenes. Since Pasteur's classical researches we know that what has really happened has been, first, the seeding of the apple juice by (wild) yeast; second, the slow growth during the quiescent period, third, its active growth and "working" during the time of obvious fermentation; and fourth, its gradual cessation of activity during the final period. In the case of the infectious disease known as smallpox the history is usually as follows: A susceptible patient must first be *exposed* to the disease, perhaps by contact with a person already affected, perhaps with clothing, letters, food, or other materials handled by such a person. After such exposure there is for a time no marked change; but because the disease has been shown by repeated experience to be nevertheless gradually developing, as judged by the result and certain obscure premonitory symptoms afterward recalled, physicians have unanimously agreed to name this the period of *incubation*. Sooner or later, headache, malaise, and other troubles appear, the patient becomes seriously and obviously ill, a physician is called in, a rise of temperature or *fever* is discovered, the eruption and other marks of smallpox appear, and the patient is plainly affected by active disease accompanied by every indication of profound disturbance and chemical change. But at last, if death does not supervene, recovery ensues, and the patient gradually becomes free from the disease by which he was temporarily overcome. We may add that the barrel of apple juice can undergo the alcoholic fermentation only once, and that the smallpox patient likewise, as a rule, has the smallpox only once. If now we tabulate side by side, and in order, the principal phenomena of an alcoholic fermentation such as that of apple juice, and those of an infectious disease such as smallpox, we shall discover a remarkable similarity between them.

The striking analogy here shown suggests something more. It certainly justifies the suspicion of relationship, and shows well the obvious fitness of the term "zymotic" (fermentative) for that class of diseases in which an analogy so remarkable is manifest.

In the next chapter we shall obtain further indications of close relationship between fermentation and disease Meanwhile, we

A Fermentation (Apple Juice)	An Infectious Disease (Smallpox)
1. Exposure of the juice to air, dust, etc.	1. Exposure of the patient to infection.
2. Repose and then slow change. (Growth of the ferment.)	2. Incubation. (Slow and insidious progress of the disease.)
3. Active fermentation or "working." Evolution of gas bubbles, change of sugar to alcohol. Rise of temperature.	3. Active disease. Eruption, disturbance of the usual functions. Rise of temperature or fever.
4. Gradual cessation of fermentation.	4. Slow convalescence (or death).
5. No further liability to alcoholic fermentation.	5. Immunity to smallpox.

cannot fail to observe that as soon as it was shown by Pasteur that the phases of an alcoholic fermentation are due to the introduction, growth, and chemical work of a living ferment (yeast) finding its way into the apple juice from the air, dust, or the outer skin of the apple, it became easy and natural to suspect that smallpox and similar diseases are somehow caused by similar living ferments finding their way into the body of the patient. Thus the "germ" theory of fermentation naturally led to a "germ" theory of infectious disease; and movement in this direction became almost irresistible when Pasteur soon after established a fact of the very first importance, namely, that *the diseases of wine and beer are "germ" diseases*, due to their invasion by, and the growth within them of, undesirable microorganisms (bacteria or wild yeasts).

General attention was now drawn to the subject, and the germ theory of disease became very widely known when Pasteur, hitherto a mineralogist, chemist, and biologist, turned aside from his laboratory studies on the fermentations of wine, beer, vinegar, and milk, and, in response to an urgent call from the French Government, began a personal investigation of a widespread animal disease, which had hitherto baffled all inquiry. This was the famous "silkworm disease" of which his son-in-law, M. Radot, has given us an admirable popular account. Inasmuch as this brilliant effort of Pasteur was one of the most important factors in drawing universal attention to the germ theory of disease, and inasmuch as it is in itself an inspiring example of a scientific grappling with disease, we may quote at some length Radot's graphic description, as follows.

Louis Pasteur and infectious diseases of silkworms.* — "The life of the population of certain departments in the South of France hangs on the existence of silkworms. In each house there is nothing to be seen but hurdles, over which the worms crawl. They are placed even in the kitchens, and often in well-to-do families they occupy the best rooms. In the largest cultivations, regular stages of these hurdles are raised one above the other, in immense sheds, under roofs of disjointed tiles, where thousands and thousands of silkworms crawl upon the litters, which they have the instinct never to leave. Great or small, the silkworm-rearing establishments exist everywhere. When people accost each other, instead of saying 'How are you?' they say 'How are the silkworms?' In the night they get up to feed them or to keep up around them a suitable temperature. And then what anxiety is felt at the least change of weather! Will not the mulberry leaves be wet? Will the worms digest well? Digestion is a matter of great importance to the health of the worms, which do nothing all their lives but eat! Their appetites become especially insatiable during the last days of rearing. All the world is then astir, day and night. Sacks of leaves are incessantly brought in and spread out on the litters. Sometimes the noise of the worms munching these leaves resembles that of rain falling upon thick bushes. With what impatience is the moment waited for when the worms arrive at the last moulting! Their bodies swollen with silk, they mount upon the brambles prepared for them, where they shut themselves up in their golden prisons and become chrysalides. What days of rejoicing are those in which the cocoons are gathered; when, to use the words of Olivier de Serres, the silk harvest is garnered in! . . .

"In the epidemic which ravaged the silkworm nurseries in 1849, the symptoms were numerous and changeable. Sometimes the disease exhibited itself immediately. Many of the eggs were sterile, or the worms died during the first days of their existence. Often the hatching was excellent, and the worms arrived at their first moulting, but that moulting was a failure. A great number of the worms, taking little nourishment at each repast, remained smaller than the others, having a rather shining appearance and a blackish tint. Instead of all the worms going through the phases

* *Louis Pasteur: His Life and Labors*, by his Son-in-Law, translated by Lady Claud Hamilton, N.Y., Appleton, 1885, pp. 127 et seq.

of this first moulting together, as is usually the case in a batch of silkworms, they began to present a marked inequality, which displayed itself more and more at each successive moulting. Instead of the worms swarming on the tables, as if their number was uniformly augmenting, empty spaces were everywhere seen; every morning corpses were collected on the litters.

"Sometimes the disease manifested itself under still more painful circumstances. The batch would progress favorably to the third, and even to the fourth moulting, the uniform size and the health of the worms leaving nothing to be desired; but after the fourth moulting the alarm of the husbandman began. The worms did not turn white, they retained a rusty tint, their appetite diminished, they even turned away from the leaves which were offered to them. Spots appeared on their bodies, black bruises irregularly scattered over the head, the rings, the false feet, and the spur. Here and there dead worms were to be seen. On lifting the litter, numbers of corpses would be found. Every batch attacked was a lost batch. In 1850 and 1851 there were renewed failures. Some cultivators, discouraged, attributed these accidents to bad eggs, and got their supplies from abroad.

"At first everything went as well as could be wished. The year 1853, in which many of these eggs were reared in France, was one of the most productive of this century. As many as twenty-six millions of kilogrammes of cocoons were collected, which produced a revenue of 130,000,000 francs. But the year following, when the eggs produced by the moths of these fine crops of foreign origin were tried, a singular degeneracy was immediately recognized. The eggs were of no more value than the French eggs. It was, in fact, a struggle with an epidemic. How was it to be arrested? Would it be always necessary to have recourse to foreign seed? And what if the epidemic spread into Italy, Spain, and the other silk-cultivating countries?

"The thing dreaded came to pass. The plague spread; Spain and Italy were smitten. It became necessary to seek for eggs in the Islands of the Archipelago, in Greece, or in Turkey. These eggs, at first very good, became infected in their turn in their native country; the epidemic had spread even to that distance. The eggs were then procured from Syria and the provinces of the Caucasus. The plague followed the trade in the eggs. In 1864 all the cultivations, from whatever corner of Europe they came,

were either diseased or suspected of being so. In the extreme East, Japan alone still remained healthy.

"Agricultural societies, governments, all the world, were preoccupied with this scourge and its invading march. It was said to be some malady like cholera which attacked the silkworms. Hundreds of pamphlets were published each year. The most foolish remedies were proposed, as quite infallible, — from flowers of sulphur, cinders, and soot spread over the worms, or over the leaves of the mulberry, to gaseous fumigations of chlorine, of tar, and of sulphurous acid. Wine, rum, absinthe, were prescribed for the worms, and after the absinthe it was advised to try creosote and nitrate of silver. In 1863 the Minister of Agriculture signed an agreement with an Italian who had offered for purchase a process destined to combat the disease of the silkworms, by which he (the Minister) engaged himself, in case the efficacy of the remedy was established, to pay 500,000 francs as an indemnity to the Italian silk cultivator. Experiments were instituted in twelve departments, but without any favorable result. In 1865 the weight of the cocoons had fallen to four million kilogrammes. This entailed a loss of 100,000,000 francs.

"The Senate was assailed by a despairing petition signed by thirty-six hundred mayors, municipal councillors, and capitalists of the silk-cultivating departments. The great scientific authority of M. Dumas, his knowledge of silk husbandry, his sympathy for one of the departments most severely smitten, the Gard, his own native place, all contributed to cause him to be nominated Reporter of the Commission. While drawing up his report the idea occurred to him of trying to persuade Pasteur to undertake researches as to the best means of combating the epidemic.

"Pasteur at first declined this offer. It was at the moment when the results of his investigations on organized ferments opened to him a wide career; it was at the time when, as an application of his latest studies, he had just recognized the true theory of the manufacture of vinegar, and had discovered the cause of the diseases of wines; it was, in short, at the moment when, after having thrown light upon the question of spontaneous generation, the infinitely little appeared infinitely great. He saw living ferments present everywhere, whether as agents of decomposition employed to render back to the atmosphere all that had lived, or as direct

authors of contagious diseases. And now it was proposed to him to quit this path, where his footing was sure, which offered him an unlimited horizon in all directions, to enter on an unknown road, perhaps without an outlet. Might he not expose himself to the loss of months, perhaps of years, in barren efforts?

"M. Dumas insisted. 'I attach,' said he to his old pupil, now become his colleague and his friend, 'an extreme value to your fixing your attention upon the question which interests my poor country. Its misery is beyond anything that you can imagine.'

"'But consider,' said Pasteur, 'that I have never handled a silkworm.'

"'So much the better,' replied M. Dumas. 'If you know nothing about the subject, you will have no other ideas than those which come to you from your own observations.'

"Pasteur allowed himself to be persuaded . . . and on June 6, 1865, started for Alais. The emotion he felt on the actual spot where the plague raged in all its force, in the presence of a problem requiring solution, caused him at once to forget the sacrifices he had made in quitting his laboratory at the École Normale. He determined not to return to Paris until he had exhausted all the subjects requiring study, and had triumphed over the plague.

"One of the most recent and the most comprehensive memoirs upon the terrible epidemic had been presented to the Academy of Sciences by M. de Quatrefages. One paragraph of this paper had forcibly struck Pasteur. M. de Quatrefages related that some Italian naturalists . . . had discovered in the worms and moths of the silkworm minute corpuscles visible only with the microscope. . . . This instrument had already rendered such services to Pasteur in his delicate experiments on ferments that he was fascinated by the thought of resuming it again as an instrument of research. . . .

"In a few hours after his arrival he had already proved the presence of corpuscles in certain worms, and was able to show them to the President and several members of the Agricultural Committee, who had never seen them. . . .

"It was necessary to know if there existed the relation of cause and effect between the corpuscles and the disease. This was the great point to be elucidated. . . .

"One of the first cares of Pasteur was to settle the question as

to the contagion of the disease. Many hypotheses had been formed regarding this contagion, but few experiments had been made, and none of them were decisive. Opinions, also, were very much divided. . . .

"But whatever the divergences of opinion might be, every one, at all events, believed in the existence of a poisonous medium rendered epidemic by some occult influence. Pasteur soon succeeded, by accurate experiments, in proving absolutely that the evil was contagious. . . . All the disasters that were known to have happened in the silkworm nurseries, their extent and their varied forms, were faithfully reproduced. Pasteur created at will any required manifestation of the disease. . . .

"For five years Pasteur returned annually for some months to Alais. The little house nestling among the trees, called Pont-Guisket, became at the same time his habitation and his silkworm nursery.

. . . . .

"All the obscurity which enveloped the origin of the diseases of silkworms had now been dispelled. Pasteur had arrived at such accurate knowledge both of the causes of the evil and their different manifestations, that he was able to produce at will either *pébrine* or *flacherie*. He could so regulate the intensity of the disease as to cause it to appear on a given day, almost at a given hour. . . . To triumph over this disease (*pébrine*), which was so threatening, Pasteur devised a series of observations as simple as they were ingenious. . . . This process of procuring sound eggs is now universally adopted.

. . . . .

"But if Pasteur brought back wealth to ruined countries, if he had returned to Paris happy in the victory he had gained, he had also undergone such fatigues, and had so overstrained himself in the use of the microscope while absorbed in his daily and varied experiments, that in October, 1868, he was struck with paralysis of one side. Seeing, as he thought, death approaching, he dictated to his wife a last note on the studies which he had so much at heart. This note was communicated to the Academy of Sciences eight days after this terrible trial.

"A soul like his, possessing so great a mastery over the body, ended by triumphing over the affliction. Paralyzed on the left side,

Pasteur never recovered the use of his limbs. To this day (1884), sixteen years after the attack, he limps like a wounded man."

Lord Lister and sanitary (aseptic) surgery. — Stirred by the investigations of Pasteur, and reflecting upon their significance, Sir Joseph Lister, already an eminent surgeon of Edinburgh, became convinced that many wound diseases are probably infectious and, if so, preventable. Accordingly, he set to work, and by the use of antiseptic dressings, sprays, instruments, etc., soon established his thesis and paved the way for the modern practice of sanitary or aseptic surgery, which was not only the first-fruit, but is also hitherto the most brilliant of the triumphs, of the germ theory of infectious disease. By its aid surgery has been not only revolutionized but also vastly extended. Operations formerly dreaded are now done with perfect assurance and constant success. The operating rooms of hospitals are built and conducted almost solely with reference to the exclusion or control of those microorganisms (germs) which are now universally recognized as the principal enemies of the patient and the worst foes of the surgeon. Lister introduced antiseptic surgery and in so doing effected a remarkable reduction in the mortality hitherto associated with surgical operations and childbirth. Eventually, however, antiseptic surgery was to give way for aseptic surgery the aim of which is to eliminate all bacteria from the wound by requiring surgically clean hands of the operator, sterile gloves, face masks, a sterile skin at the site of the operation, sterile instruments, sterile dressings and an atmosphere entirely freed of bacteria by washing. But even today, during war, earthquake, flood, or other major emergency, when the facilities of civilization are temporarily not available, recourse must be had to antiseptic surgery. The World War demonstrated further through the use of the Carrel-Dakin solution in the treatment of wounds, that greater progress could be made in the healing of serious injuries through the gradual sterilization of the affected area. The world will ever remember these simple but invaluable applications of Pasteur's researches to the conquest of the pyogenic infections.

CHAPTER III

THE RISE AND INFLUENCE OF BACTERIOLOGY

The achromatic microscope objective. — Reference was made in the last chapter to the influence of the newly discovered achromatic microscope objective upon the development of the germ theory of fermentation and its corollary the germ theory of disease. Its aid was also now being felt from a somewhat different direction, namely, from purely zoölogical and botanical studies of the lowest forms of life. Pasteur's studies on the diseases of wines, beers, and silkworms, and on the "organized corpuscles" of the air, had pointed downward into the world of the "infinitely little" as the source of those "germs" of life which seemed so small and yet so potent in fermentation and disease. All eyes, therefore, were turned in that direction, and extreme interest and curiosity were felt to know all that could be learned of the lowest forms of life, popularly described as "germs." This interest and curiosity were intensified, no doubt, by the rise just at this time of Darwinism, which also pointed downward for the beginnings of organic species to equally mysterious microscopic and primitive "germs" of life. As a result of these various inquiries one group of microorganisms or germs, the *Bacteria*, then only recently studied by botanists, became and has ever since remained of the first importance to sanitarians.

Animalcula, vibrionia, bacteria. — The compound microscope is believed to have been invented about the end of the sixteenth century by Jansen, and microörganisms, some of which were probably bacteria, were seen by Kircher (1658), figured by Leeuwenhoek (1683), and because they were capable of motion, received the name *Thierchen* or *animalcula, i.e.*, "little animals" or "animalcules." The compound microscope of the seventeenth century, however, was a very poor instrument and that of the eighteenth century, little, if any, better. The best evidence of these facts is that many microscopists actually abandoned the use of the compound microscope of the day, preferring the simple microscope of lower power with comparative freedom from the aberrations of

the compound instrument of the time with its colored and distorted images. We need not be surprised, therefore, to learn that the microscopists of the eighteenth century made but small progress in the territory of the "animalcules." The first important and extensive advance upon the work of Leeuwenhoek was made a hundred and fifty years later, and with the aid of the newly discovered achromatic objective, by Ehrenberg (1838) and his contemporaries. The vast horde of forms originally called "animalcules" had, it is true, by this time been separated into two or three main divisions, only one of which is of consequence to us, namely, the *Vibrionia,* a group of the *infusorial animalcules;* and in 1850 the suspicion for the first time found expression that these are not all, or necessarily, animal forms. In 1857 Nägeli, the distinguished botanist of Munich, definitely and finally classified the *Vibrionia* as plants, giving to them the name of *Schizomycetes* — "fission plants." To show that the earlier names still prevailed for a time, however, we need only mention the fact that Pasteur in his earlier papers frequently refers to these forms as "infusorial animalcules" or "corpuscles." A long step forward was made when, in 1872, Ferdinand Cohn, of Breslau, began the publication of a series of papers entitled *Investigations on Bacteria.** From that time onward the terms "bacteria," "microbes," and "microorganisms" have been largely used. The two latter terms are useful as including animal as well as plant forms; and all of these terms may be said to be partial modern equivalents of the older term "animalcules." All of them include living "ferments" capable of producing profound, though often invisible, changes in organic substances, and of causing singly or in cooperation those mysterious processes called fermentation, putrefaction, decay, and sometimes infectious disease.

The foundations of bacteriology laid by Louis Pasteur. — It has already been told in the previous chapter how the labors of Louis Pasteur served to establish the "germ" theory of fermentation and prepared the way for a "germ" theory of disease. His labors bore fruit also by laying for all time the secure foundations of what has since come to be a new branch of science, namely, bacteriology. Pasteur was not the first to use the microscope in studies on fermentation, but he was the first to employ careful *cultivations* of the microörganisms concerned, and special im-

* "Untersuchungen über Bacterien," *Beiträge zur Biologie.*

portance belongs to his constant attempts to secure "pure cultures" of yeast and other living ferments. It is true that he was compelled to rely altogether upon *liquid* cultivation, so that the actual purity of his cultures is open to some question; but there is no doubt whatever that by his ingenious and successful use of these so-called "pure cultures" — which led him to the discovery of specific causative germs in certain specific diseases of wines and beers, as well as in normal fermentations, such as the acetic and lactic, not to mention the specific "corpuscles" of the silkworm diseases — Pasteur earned the high privilege of being regarded as the "founder" of bacteriology. It may be well to state at this point, by way of anticipation and in order to avoid misunderstanding, that the honor of establishing bacteriology as a science, upon the foundation laid by Pasteur, belongs to Robert Koch, who, by proving (in 1876) that bacteria are the cause and not the consequence of a particular disease (anthrax) and by introducing (in 1881) an indispensable method of cultivation -- the method of "solid" as opposed to "liquid" cultures — raised bacteriology from a previously dubious position to one of high honor among the biological sciences.

Microörganisms the cause and not merely the consequence of disease. — The germ theory of disease was not without strenuous opponents. In particular, the objection was raised that there was as yet no evidence that the germs observed in any disease might not have been caused by the disease itself, they being the consequence and not the cause of it. This was really a sound and valid objection. It had been successfully raised by Liebig against Cagniard de Latour and Schwann, the discoverers of yeast as a living ferment, as early as 1839, and had been silenced in the case of Pasteur's studies on fermentation only with difficulty and by means of his use of needle inoculations and practically pure liquid cultivations. It was now (1865–1875) urged with reason and with vehemence because many absurd claims were being made regarding the discovery of the "germs" of various diseases, based upon mere observation of microbes in the bodies of persons suffering from those disorders or else detected in their food or drink. In such a case it was entirely possible for anyone to urge that the patient had first fallen ill and had then been invaded by the germs, the disease being primary and the germs purely secondary and adventitious. This view was forever disproved, and bacteriology

for the first time established on a scientific basis by the splendid researches of Robert Koch upon splenic fever, or anthrax, between 1875 and 1878. Koch was a young physician of Wollstein, in Prussia, when he began his studies on anthrax. This disease was not rare in Germany, Russia, and other parts of Europe, and affected mainly cattle, sheep, and horses, but also, at times, human subjects. On examining the bodies of cattle dead of anthrax, Koch found with the microscope (as Davaine did in 1863) minute rods or sticks in the blood and other organs, and especially in the spleen. To some observers this had seemed enough to prove that these were the "germs" of the disease; but Koch did not rest here. Following the methods already employed by Pasteur in his researches on yeast, Koch transferred a needleful of blood or other tissue charged with the mysterious rods to a relatively large portion of the clear normal liquid which constitutes the aqueous humor of the ox's eye. After a few days, or even hours, the rods, being alive and able to grow in this liquid, had multiplied enormously, while the portion of tissue carried over with them being dead had not increased but rather diminished. From this first dish a needleful was now similarly transferred to a second large and fresh portion of aqueous humor, which was thus seeded in its turn. From this second a third was eventually seeded, and so on. A little reflection will show that at each transplanting, though many of the rods were carried over, very little, and always less and less, of the original tissue was transferred. Moreover, the rods transplanted soon included few or none of the original rods derived from the diseased animal, but only the innumerable descendants of these in more and more remote generations. It is easy to see that after a number of transplantings not only none of the original diseased tissue could have remained — those things only being represented that had the power of life, growth, and reproduction, but also none of the original "germs." This method of cultivating the living plants — for the rods are plants — was clearly a kind of horticulture, and it has become known as the method of liquid "cultures." It should not be forgotten that it was first used successfully (for yeast) by Louis Pasteur. If as a result of its use only one kind of microörganism (yeast, bacterium) finally remains, such a culture is said to be "pure," or "a pure culture"; precisely as a wheat field free from everything but wheat would be a "pure culture" of wheat. Moreover, just as the ripe grains of wheat in

a wheat field are not those which were planted but only their offspring, so the rods in Koch's cultures of the third or tenth generation were not those originally sown by the needle or directly derived from the diseased animals. But if the rods so derived really caused the disease known as anthrax, then their own offspring might reasonably be expected to have similar properties and powers, precisely as wheat grains have the properties of the seed wheat. Accordingly, Koch proceeded to inoculate healthy susceptible animals with his pure cultures of anthrax rods, rightly thinking that if these were the germs of the disease they should be able to reproduce it. The result was perfectly conclusive: the inoculated animals promptly died of typical anthrax, and proof now existed, for the first time in the history of pathology, that a specific germ was and is the cause, and not merely the accompaniment or the consequence, of at least one well-known specific, infectious animal disease.

An immediate result of this brilliant work of Koch was to give a fresh stimulus to the study of the bacteria, already in full cry since the beginning of the classic researches of Cohn, who, in 1876, added to his earlier results the highly important discovery that some bacteria can, and under certain circumstances do, produce *spores* which appear to be protective, highly tenacious of life, and very resistant to destruction by drying, heat, poisons, etc. Moreover, Koch not only readily discovered spores in the rods of anthrax, but also succeeded, as only a very few observers had done before him, in finding on other germs — notably certain large spiral forms in ditch water — flagella or lashes in active motion and presumably locomotor in function. These he even succeeded in photographing for the first time in 1877.*

The establishment of bacteriology as a recognized biologic science by Robert Koch in 1881. — Bacteria were probably first discovered in the latter part of the seventeenth century by Kircher and Leeuwenhoek, as has been stated already, but it was not until 1857 that microscopists were able to classify them, and to locate them definitely in a natural system. Owing to the intrinsic and peculiar difficulties of the subject but little headway was made in exact knowledge of the bacteria themselves, and bacteriology as a distinct science was not established until, in 1881, the new and vastly improved method of cultivating bacteria was introduced

* Cohn's *Beiträge*, Bd. II.

by Robert Koch. This method of cultivation which immediately proved so valuable is familiar to all biologists and is known as "Koch's method of solid cultures," whereas up to 1881 all cultures of yeast or bacteria hitherto made had been "liquid" cultures. This was tedious, uncertain, unsatisfactory, and in the hands of any but experts almost sure to lead to wrong conclusions. Thus it happened that during the twenty years after Pasteur began to use liquid cultures, progress in bacteriology was slow and uncertain. We shall now see why, on the contrary, in the same number of years since Koch began his use of "solid" cultures, bacteriology has advanced by leaps and bounds.

The method of solid culture overcomes the worst defects of the method of liquid culture, namely, first, the promiscuous mingling of different kinds of bacteria, and also, second, the time and labor consequently required to secure "pure" cultures. In this method the bouillon, or other liquid medium in which bacteria will thrive, is simply thickened while warm with gelatin or some similar substance such as Irish moss or agar-agar, so that when cooled the mass becomes a firm moist jelly, at room temperature, and in the case of nutrient agar, at body temperature as well. It will be apparent on a moment's reflection that any bacteria or similar microorganisms present in the liquid must also be present in the solid mass, but with this important difference of condition, viz., that whereas in the liquid they float or swim about promiscuously, and may become thoroughly intermingled, such is not the case in the solidified mass, in which each cell is invariably brought to rest and held captive at some small distance at least from every other. Moreover, since the "solid" medium contains as abundant nutrients as the "liquid," the bacteria are firmly fixed in a solid which is at once their prison and their food. Accordingly, they continue to feed and multiply or reproduce, though each remains fixed at or very near the point where it was imprisoned. After a day or two, as a result of continued feeding and reproduction, microscopic heaps of bacteria are formed, which finally become visible to the naked eye as minute dots, and when still larger are known as "colonies." If the parent of the colony was, as is usually the case, a single isolated, individual bacterium, the colony, being composed solely of the descendants of this germ, will be a "pure" culture, readily and immediately supplying the material for other pure cultures of the same species. The ease and the

saving of time, the simplicity, certainty, and accuracy of the method are obvious. Its superiority to the method of liquid cultures caused its immediate adoption, and it speedily led to the establishment of bacteriology as a recognized biological science.

Almost immediately the new science began to yield wonderful fruit, for in the next year 1882 the whole world was startled at the announcement by Koch of his discovery of the microörganism of tuberculosis, a bacillus usually found in the sputum of patients suffering from consumption, capable of cultivation on solid media outside the human body, and able to produce the disease when inoculated into healthy susceptible animals, such as guinea pigs. This announcement caused a profound sensation all over the world; but so general and so conclusive was the confirmatory testimony, that in a surprisingly short time it was accepted, and is now a matter of history. The year 1884 witnessed the discovery, also by Koch, of the microorganism of Asiatic cholera, in this case not

TABLE 4

SOME SIGNIFICANT DISCOVERIES IN BACTERIOLOGY

YEAR	ORGANISM	WORKER
1876	B. anthracis	Koch
1879	Diplococcus (Neisseria) gonorrhoeae	Neisser
1880	B. (Eberthella) typhosus	Eberth
	Plasmodium malariae	Laveran
1882	B. (Mycobacterium) tuberculosis	Koch
1884	Vibrio cholerae	Koch
	B. (Clostridium) tetani	Nicolaier
	B. (Corynebacterium) diphtheriae	Klebs-Loeffler
	Staphylococcus pyogenes	Rosenbach
	Streptococcus pyogenes	Rosenbach
1885	B. (Salmonella) suipestifer	Salmon and Th. Smith
1886	B. (Escherichia) coli	Escherich
	B. (Actinobacillus) mallei	Loeffler and Schutz
	Diplococcus pneumoniae	Weichselbaum
1888	B. (Salmonella) enteritidis	Gaertner
1889	B. (Salmonella) aertrycke	De Nobele
1892	B. (Clostridium) welchii	Welch and Nuttall
	B. (Hemophilus) influenzae	Pfeiffer
1894	B. (Pasteurella) pestis	Yersin and Kitasato
1896	B. (Clostridium) botulinum	Van Ermengem
1898	B. (Shigella) dysenteriae	Shiga
1900	B. (Salmonella) schottmülleri	Schottmüller
1905	Treponema pallidum	Schaudinn and Hoffman
1906	B. (Hemophilus) pertussis	Bordet and Gengou
1923	Streptococcus scarlatinae	George and Gladys Dick

TABLE 5

SOME SIGNIFICANT DISCOVERIES IN IMMUNOLOGY AND MODES OF TRANSMISSION OF CERTAIN DISEASES

Year	Discovery	Worker
1796	Vaccination against smallpox	Edward Jenner
1881	Immunization against anthrax	Pasteur
1885	Immunization against rabies	Pasteur
1890	Antitoxin against tetanus	Behring and Kitasato
1890	Antitoxin against diphtheria	Behring
1893	Ticks transmit Texas (cattle) fever	Th. Smith and Kilborne
1898	Bacterial vaccine against typhoid	Wright
1898	Life cycle of malarial parasite	Ronald Ross
1900–1901	Mosquitoes transmit yellow fever	Reed, Carrol, Lazear, and Agramonte
1913	Schick test for diphtheria susceptibility	Schick
1913	Toxin-antitoxin for diphtheria immunity	Behring
1921	Toxoid for diphtheria immunity	Glenny
1924	Dick test for scarlet fever susceptibility	Dick and Dick
1924	Scarlet fever toxin for active immunity	Dick and Dick
1924	Scarlet fever antitoxin for treatment	Dochez

a true *bacillus* or rod, but a curved form; hence at first described as a "comma" bacillus and afterward as a *spirillum* or *vibrio.* The same year (1884) yielded the rich prizes of the bacillus of diphtheria and that of tetanus (lockjaw), as well as new and careful studies by Gaffky, with the improved methods, upon the bacillus of typhoid fever which had been partially worked out previously by Eberth and Koch. Very much, of course, still remained to be done, not only in the search for the germs or living ferments of important and familiar diseases, but also in verifying the steps already taken; but it is no exaggeration to say that within five years from the time of Koch's introduction of the method of solid cultures the new science of bacteriology had achieved a recognized and honorable position.

The decade from 1880 to 1889 is often referred to as the Golden Age in Bacteriology, and was indeed rich in discoveries concerning the etiology of communicable diseases and in the embryonic science of immunology. But the years that followed proved equally rich and rewarding, albeit much of the pioneer work had been done, until today Bacteriology and its associate pursuit, Sanitary

Science, command world-wide interest and support, with laboratories at their disposal that are temples of endeavor, and some of the best minds of the human race as their constant disciples. In order to make the outstanding achievements in these fields as clear as possible, tables 4 and 5 have been prepared giving in chronological order the discoveries that are noted, and the workers whose industry and skill have helped to make the world a habitable haven for man.

How, precisely, do living ferments produce disease? — A little reflection will show that there are several ways in which invading microorganisms might conceivably produce disease in the animal body; for example, (1) *by mere physical obstruction*, clogging the capillaries, veins, and arteries, and interfering mechanically with the ordinary operation of the vascular and other mechanisms; or (2) *by chemical interference*, such as (*a*) theft of food or other chemical compounds needed by the body, or (*b*) by the generation of substances harmful to the body and therefore to be reckoned as essentially poisonous or "toxic." It is not necessary to do more than suggest these various possibilities inasmuch as it is now universally agreed that, while other influences should not be overlooked, the principal method of damage lies in the generation of toxic products (*toxins*), resulting from the operation of living ferments within or upon the organism. Some of these toxins or poisons are given off outside the bacterial cell, such as the toxins of the diphtheria bacillus, the tetanus bacillus, the botulinus bacillus, and the streptococcus of scarlet fever. These are known as exotoxins or extracellular toxins. Other organisms capable of producing disease do not secrete toxins outside the cell, but have toxins inside the cell. These, too, are capable of producing disease and death. Among such organisms may be listed the germs of typhoid fever, dysentery, tuberculosis, and pneumonia. Such toxins are known as endotoxins or intracellular toxins. Every pathogenic organism has a mechanism by which it brings potential or real injury to the body it invades. Where injury occurs it is due to the elaboration of toxic products capable of producing the symptoms of disease. Toward the understanding of this condition much has been done. The researches of the past fifty years have yielded likewise a great deal of information on the treatment and prevention of certain communicable diseases through the use of biological agents. Some of these will be described in a subsequent section.

CHAPTER IV

SANITARY ASPECTS OF THE STRUGGLE FOR EXISTENCE: FACTORS AFFECTING SURVIVAL

Sanitary aspects of the struggle for existence. — In the preceding chapters stress has been laid on the potency of the agents of disease proceeding from the environment. This, however, is only one aspect of the matter. In order that living ferments or their poisons shall be effective, there must be a susceptible subject upon which they can act. Thus in any zymotic disease the energy and virulence of the attacking agents are virtually pitted against the resistance of the patient, and a struggle ensues which may be, and often is, on one side or on both sides a veritable struggle for existence. In this case the struggle is between organism and organism, between man and microbe. In *The Origin of Species* Darwin, in dealing with the struggle for existence, dwells chiefly upon similar struggles of living things one with another, and it is this aspect of the subject which is still most often emphasized. For the hygienist, however, the struggle for existence means not only competition and battle and their consequences, not only the struggle of organism with organism, but also the broader struggle of the individuals with their whole environment. In the familiar parable of the sower we have a vivid picture of such a struggle for existence in the case of certain seeds:

"Behold, a sower went forth to sow; And when he sowed, some seeds fell by the wayside, and the fowls came and devoured them up: Some fell upon stony places where they had not much earth; and forthwith they sprung up, because they had no deepness of earth: And when the sun was up, they were scorched; and because they had no root, they withered away. And some fell among thorns; and the thorns sprung up, and choked them: But others fell into good ground, and brought forth fruit."

In this parable both aspects of the struggle for existence are dwelt upon: first the struggle of organism with organism, namely, of seeds with birds and with thorns; and, second, of organism with lifeless environment, namely, with stony places, scorching

sun, and good earth. A similar breadth of view is required for the student of sanitary science who seeks to gain a philosophic knowledge of the nature of disease; for disease may be the consequence not merely of organism struggling with organism, but also of organism struggling with lifeless environment. It is perhaps most often the result of both hostile organism and unfavorable lifeless environment acting together upon the human mechanism. Of the struggle of organism with organism parasitism affords a familiar and instructive example.

Parasitism and infectious disease. — Some recognition of what is now known as parasitism must have occurred very early in the history of the human race. It is exemplified, for example, in the case of the gourd which grew up and sheltered Jonah while he impatiently waited for the destruction of Nineveh, inasmuch as a worm was sent in the night to feed upon and destroy the gourd. It is said that Pliny was familiar with the parasitism of the mistletoe. The word "parasite," however, arose in a different connection and was only recently applied to plants and the lower animals, having been apparently first used for a person who unbidden eats beside, or at the table of, another, and therefore, of course, lives at his expense. A few cases of parasitism, such as that of the mistletoe, were recognized very early because they were so conspicuous that they could not readily be overlooked. The well-known lines of Swift * testify unmistakably to a recognition of the same phenomenon. For the most part. however, parasitism remained comparatively unrecognized until the introduction of the compound microscope revealed its almost universal prevalence.

Parasitism is now known to be one of the commonest features of the struggle for existence, and it is not necessarily, as it is often supposed to be, an abnormal and strange development — at least in its beginnings. If, in the search for food, a plant or animal happens to come in contact with and feed upon another, it may

* "So, naturalists observe, a flea
Has smaller fleas that on him prey;
And these have smaller still to bite 'em.
And so proceed *ad infinitum*."

Of which a more popular, alliterative, and generalized version is —

"Big bugs have little bugs
Upon their backs to bite 'em;
And little bugs have lesser bugs,
And so *ad infinitum*."

easily result that it shall gain great profit thereby, though if this habit becomes so extended as to lead to the destruction of the host, the parasite itself may also perish. It is not difficult to suppose that parasitism may have arisen from saprophytism, in which plants or animals feeding upon dead or waste organic matters happened to become attached to living plants or animals, and it is easy to see how, under these circumstances, great advantage might accrue to the saprophyte. It is even possible to imagine how the ranks of parasites, thinned by the destruction of their hosts, or otherwise, might continually be recruited from among the saprophytes.

The somewhat extended discussion of the germ theory of fermentation and disease in the previous chapter should not lead the reader to overlook the fact that many of the microorganisms which are the prime movers of fermentation and infectious disease must from another point of view often be regarded as parasites. The parasitic fungi have long been known in special cases to penetrate the tissues of their host precisely as microbes may "invade" the animal body. It has also been known that in doing this some solvent reagent was secreted by the fungus, and experiments have shown that it is possible to separate from particular fungi substances which will corrode and destroy vegetable tissues. It thus appears that a close analogy is discoverable between the toxins or poisonous products of disease germs and these solvent reagents or tissue-poisons.

It is customary to speak of the infectious diseases as essentially parasitic in their character, the disease germs being the parasites, and the organisms affected their hosts. This point of view is not only common, but exceedingly useful, for it places these diseases in the same category with certain well-known phenomena of parasitism (or saprophytism), and makes them thereby the more readily comprehensible. The sanitarian in particular has reason to value this interpretation of infectious disease inasmuch as prevention of parasitism is, in theory at least, a comparatively simple matter, namely, the destruction of the parasites in question and their control in the environment. When it comes, however, to an examination of the precise nature of the parasitism involved in infectious disease, we shall find it often necessary to regard the germs as parasites producing chemical change and doing damage by the chemical changes which they effect, or the chemical bodies

which they produce, rather than by the theft of food substances which is the more ordinary characteristic of parasitism.

The lifeless environment and disease. — Any extended treatment of this subject would be beyond the province of a work like this. Nevertheless, the influence of the lifeless environment as a powerful factor in the causation and modification of infectious disease, cannot be neglected even when it is not the principal factor. In such disease, for example, the time, the occurrence, the duration, and even the energy of the attack, may be profoundly influenced by external environmental conditions such as season, temperature, dryness, or light. We may, therefore, with advantage, consider somewhat carefully the relations between organisms and their environments, whether living or lifeless, before passing on to the more recondite subjects of susceptibility, vital resistance, and immunity.

In addition to a comprehension of the fact that the living organism is essentially a delicate physical mechanism, the student requires an adequate knowledge of what is meant by the terms "organism" and "environment," and with this a recognition of the significance of the actions, reactions, and interactions which necessarily go on between organisms and their environments.

In the language of biology an organism is a limited mass of living matter occupying a definite position in space and time. It is bounded on all sides by material substances — earth, air, water, etc. — by which it is acted upon, and upon which it acts in return, and, on the whole, these actions and reactions are equal, though in opposite directions. Those portions of the material universe which thus act upon the organism are called its "environment," and a little reflection will show that while it is the nearer portions which are most closely concerned and are, therefore, the most conspicuous parts of "the environment," no part, in theory at least, is so remote as to have no influence. The whole material universe may be — must be — divided for any living thing into two parts, namely, that thing and its environment: the individual on the one hand, and the rest of the universe on the other — very much as the ancient and mediaeval philosophers regarded man on the one hand as "microcosm" and the rest of the universe as "macrocosm." Biology teaches that if we would comprehend the doings of living things we must begin by taking this point of view. Viewed from this standpoint mankind becomes a host of masses

of matter each bounded by the rest of the material universe, with which it must deal so long as it continues to live, and to which, no matter how prolonged the struggle, it must finally surrender. From the environment each must derive whatever of matter and energy it gains, and to it it must return whatever it loses. It may be profoundly affected by heat or cold, by lightning or earthquake, by fire or tempest; and it may, on its part, react upon its environment and displace the air by buildings or balloons, the sea by ships, the earth by mines or tunnels, or fire by incombustible substances. Every tree that lifts its branches into the aërial ocean reacts upon the atmosphere and, like every animal that burrows into the earth or builds its house or its nest in the air, reacts upon its environment. The encroachments of the sea may be resisted or overcome by dikes, of the wind by shelters, of the sunshine by shade. Everywhere in nature — and in man as a part of nature — we find actions and reactions incessantly going on, and these in the long run consist essentially of exchanges of matter and of energy or of both, between masses of matter and their environments.

Health and disease in terms of general biology. — Life has been defined as "the continuous adjustment of internal to external relations," and health might be defined on these terms as the normal state and performance of this adjustment. Disease would then be some serious disturbance or grave departure from this normal state or performance, and might conceivably be due to (1) a failure of the intrinsic powers of adjustment; or (2) some external condition so severe or unusual that the usual adjustment was impossible; or (3) to a combination of these factors. A very little reflection will show that to avoid disease and to forestall its effects there are required: (1) Mechanisms as capable as possible of adjustment to external relations, unfavorable as well as favorable. (2) Environments (external relations) to which the mechanism may readily adjust itself, or making as small demands as possible upon its powers of adjustment. Of these two factors the former is on the whole far the less under our control at present. The mechanism may indeed, as a rule, be strengthened by good air, good food, rest, and other favorable conditions; it may be weakened by bad air, bad food, fatigue, and other unfavorable conditions; so that it shall adjust more or less successfully its internal to any external relations.

Three principal sanitary conditions or states of relation. — In actual life all these various conditions are readily observed. We find some persons so robust — that is to say, with mechanisms so capable of adjustment to external relations of whatever kind — that nothing seems to daunt them. They work hard, eat poor food, live in bad air, and seemingly disobey all the rules of hygienic living, and yet possess apparently perfect health. Conversely, others surrounded by every sanitary contrivance, well fed, well housed, and tenderly cared for, sicken and die in an environment apparently the most absolutely favorable. And finally, in the same community, are many who thrive as long as their external relations are good and easily dealt with ("favorable"), but who suffer just as soon as these become difficult to deal with ("unfavorable").

Furthermore, these groups are by no means fixed and invariable, but rather constantly subject to change both as to membership and mass. A period of unusual environmental severity of climate, temperature, infection, financial or political buoyancy or depression, may promote or reduce from one rank to another, with the consequence not only of numerous changes in actual sanitary conditions in individuals, but even extensive improvement or deterioration in the average public health of a community. Of this a good example is some effective change in external relations, such as a financial panic, causing anxiety, loss of employment, increased exposure, poorer feeding, loss of sleep, etc., but perhaps the best example is one in which a novel and direct action proceeds from the environment, unknown, it may be, until its work is done. Such a profound change in the external relations of an entire community occurs when some epidemic, unsuspected, falls upon an entire city or town. There are on record many cases of this kind, some of which are described later. If, for example, a public water supply becomes contaminated with the germs of an infectious disease such as typhoid fever, the general standard of health in the community using it will be lowered, the weak, as a group, will, on the whole become weaker, the strong, less strong, and some of each group will perish altogether who would have lived longer if the infection had not reached them.

The explanation of these three great groups — which we may call "the robust" or "the strong," "the well but not strong," and "the feeble" or "weak" — is simply that there are actually corresponding groups of organisms, or mechanisms, in every com-

munity. The "strong" are those endowed by nature, by inheritance, or it may be to some extent by training, with superior vital machinery. "The well but not strong" are similarly provided with machinery either poorer in quality or less successfully put together, while the "weak" or "feeble" are those having vital mechanisms so delicate in fiber or adjustment as to be always in need of attention or repair, even under ordinarily good conditions. Few, comparatively, are able to adjust their internal to their external relations so successfully as to reach the familiar threescore years and ten; fewer still the fourscore years; and we have the authority of the psalmist that in the latter case it is only "by reason of strength" that the goal is reached: favorable environments — favorable external relations — alone are not sufficient. The power of adjustment of internal relations is equally indispensable.

Vital resistance and susceptibility. — The reader is now in a position to understand in its general aspects the term "vital resistance." In the last analysis this expression is used to describe that condition of the normal body, plant or animal, in which it is able to cope more or less successfully with unfavorable influences acting upon it from without, *i.e.*, from the environment. There is, however, no quantitative measure of vital resistance; but when it is regarded as small or altogether wanting, the term is no longer used, and the organism is said to be not vitally resistant, but "susceptible" or "vulnerable" to disease. At the other extreme, when the vital resistance is complete, especially in regard to parasites, poisons, etc., the organism is said to be "immune," as are, for example, the arsenic eaters of Styria against ordinarily lethal doses of arsenic, and as are certain trees to certain parasites.

Immunity. — Examples of comparative immunity to infectious disease are familiar in the cases of all robust and healthy persons. Precisely what the basis of this immunity may be it would be difficult to say, but it is not inconceivable that in an organism which is a practically perfect mechanism the conditions should be such as to ward off effectually all microörganisms, either by mechanical or physiological defenses. Among the former would be healthy and vigorous skins and epithelia, which the invaders should find it impossible to penetrate; among the latter, fluids of the body of such composition as to be essentially toxic or destructive for invading microbes. There is good reason to believe that such

conditions are, in fact, some at least of those which constitute the robustly healthy organism immune to all ordinary infectious diseases. For example, an unbroken skin or mucous membrane provides excellent protection against the invasion of the body by pathogenic microörganisms from the outside, while the acid normally present in the stomach and the secretion from the tear glands are illustrations of special secretions which destroy bacteria in large numbers and which aid the body in warding off infection and disease.

Immunity to smallpox. Inoculation. — The development of our knowledge in this direction is interesting and instructive. The first systematic steps toward securing artificial immunity from disease appear to have been taken in the case of smallpox. In the early part of the eighteenth century, Lady Mary Wortley Montagu, the wife of the British ambassador at Constantinople, and a woman of rare gifts, in interesting letters sent from Constantinople to friends at home pointed out that the Turks, in pursuance of a custom apparently derived from the East, were in the habit of "inoculating" against smallpox. Lady Montagu wrote from Adrianople in 1717: "Every year thousands undergo this operation, and the French ambassador says pleasantly that they take the smallpox here by way of diversion, as they take the waters in other countries. There is no example of any one having died of it, and you may believe I am satisfied of the safety of their experiment since I intend to try it on my dear little son." Largely as a result of this correspondence the practice of inoculation was introduced into England, and thence carried to America. In both countries it became widely extended, and lasted for many years. It is said that the first person inoculated in England was Lady Montagu's daughter. George I and several members of his family were soon after inoculated, as were also many less noted persons, and the practice gradually became common.

In the process of inoculation for smallpox, some "matter" derived from a pustule of a smallpox patient was introduced under the skin of a healthy person who elected to suffer from the disease while well, and knowingly, rather than to run the risk of "taking" it when less well, unknowingly. The process was much the same as that employed in vaccination except that the "matter" used was derived directly from the pustules of a smallpox patient, and was not "vaccine" matter, *i.e.*, was not derived either directly or

indirectly from the cow. Inoculation had a very extended vogue and was justly regarded as a most important defense against smallpox; and until the milder method of inoculating "vaccine" matter, *i.e.*, matter derived from the cow, was devised by Jenner, no other method of prevention of smallpox, or, for that matter, of any infectious disease, was known or practised.

The drawback to inoculation was that persons inoculated had for the time being mild cases of genuine smallpox, and were therefore capable of conveying the disease to others. They became, temporarily at least, "foci of infection," and were usually treated as such, being often gathered together in inoculation "hospitals" or establishments in relatively remote and inaccessible places, and kept meanwhile under more or less strict quarantine regulations. Those who voluntarily resorted thither for inoculation naturally went, or were sent, while in good health, and, for the time being, were completely separated from their families. It was a successful, but rather dangerous and troublesome method of combating the disease, and when vaccination, equally and perhaps more protective and neither difficult nor dangerous, was introduced (in 1796), inoculation fell into disrepute and was finally forbidden by law (in 1840, in England). Like its successor and superior, inoculation of *cowpox* (vaccination), the practice of inoculation of smallpox met with strenuous contemporary opposition, but the esteem in which it was held by the most eminent physicians and scientific men of the time is sufficient evidence of its value.

The attitude of mankind at various times toward smallpox, inoculation, and vaccination forms one of the most remarkable chapters in the history of the human race. It is impossible today to realize the dread and awful terror with which this horrible and most loathsome disease was justly regarded by our ancestors before the introduction of inoculation and vaccination. A single brief quotation may help to give the reader some idea of the feeling in regard to it and its prevalence, even as late as the middle of the eighteenth century. "Smallpox has been for ages, and continues to be, the terror and destroyer of a great part of mankind. . . . In the ordinary course and duration of human life scarce one in a thousand escapes the smallpox." * . . . It would be easy to multiply authoritative statements of the fearful ravages of this

* Appendix to Dr. Brooke's *General Practice of Physic*, London, 1766.

disease, and to bring forward testimony to its abundance, contagiousness, and foul character. Fortunately, it has become today in civilized countries so uncommon that the former dread of it has largely disappeared from the popular mind. Unfortunately, however, unfamiliarity with it has bred a contempt for it which leads many to despise, undervalue, or refuse the means by which it is chiefly kept in abeyance. Such contempt is likely, if it becomes general, to carry with it its own punishment, for smallpox is so contagious that its recrudescence at any time in any community is natural and easy, if the very simple means in our possession for holding it in check are long neglected.

It is difficult for those who are alive today to realize that only 100 years ago (around 1830–1840), 20 per cent of all children died of smallpox before they reached the age of 10, and that one-third of all the deaths occurring among children from all causes were due to smallpox. And yet it must be admitted with regret and shame that in an era when an effective preventive was available, and in the face of constant propaganda advocating its use, there should have been reported in the United States during the decade from 1919–1928, a total of 553,559 cases of smallpox.

Vaccination. — Vaccination (*Vacca,* cow) is simply a modification of inoculation in which "matter" of cowpox taken originally from the cow is substituted for "matter" of smallpox taken from man. Whatever the reason, it is now an established fact that inoculation of the matter of cowpox into the body of human subjects prevents or weakens the virulence of smallpox infection. This immortal discovery of Jenner in 1796 has led to the view, supported by the experience of the race, that by its universal application smallpox can be not only held in check but virtually exterminated.

In its infancy vaccination, like inoculation, had to encounter strong opposition based upon ignorance and a natural dread. The remarkable fact is that long after its success has been abundantly demonstrated, and after its period of "infancy" may be regarded as having been long since passed, the practice of vaccination should still be not only rejected but also violently attacked by some persons of intelligence. The fundamental reason for this paradoxical state of things is doubtless due to the "extraordinary" character of a treatment which consists in "inoculation" of any kind. Persons who of their own motion or on the advice of their

physicians will cheerfully and even eagerly swallow "medicines," often of a poisonous character, the very names of which are unknown to them, will sometimes refuse to obey their medical advisers when they recommend vaccination — the former custom being "ordinary" and hoary with age, the latter still comparatively novel and "extraordinary."

Pasteur and attenuation. — While germs or microbes characteristic of smallpox or of cowpox have never yet been satisfactorily isolated, analogy compels us for the present to assume their existence. A consideration of the corollaries resulting from the application of the germ theory to these long-known and world-famous diseases led Pasteur, in 1877, not indeed to a solution of the problem of immunity, but to an important extension of the art of vaccination, and new and interesting examples of the immunity-phenomenon. Pasteur reasoned that, if an infectious disease be really a struggle for supremacy between man and microbe, it is probable that in vaccination for smallpox the struggle is less severe for the patient because the germs of smallpox have somehow been weakened or enfeebled by their residence in the cow. If this hypothesis were correct, he might hope to lessen the virulence of any microbe by subjecting it to an unfavorable environment or treatment. Heat, cold, dilution, starvation, overfeeding, etc., suggest themselves as possible agents for weakening virulence; and by experiment Pasteur actually produced enfeebled or "attenuated" cultures of anthrax, chicken cholera, etc., with which he was able successfully to "vaccinate" (if the term may still be used) various animals, rendering them more or less immune to the diseases respectively investigated. In a dramatic public demonstration, in 1880, Pasteur proved conclusively the practicability of his method, which, since that time, has passed into common use in France for the vaccination of domestic animals.*

As a result of Pasteur's labors, fresh examples of immunity were provided, and the practicability of its artificial production was strongly emphasized; but the basis of immunity or the physiological mechanics by which it comes to pass and persists remained as great a mystery as ever.

Metschnikoff and phagocytosis. — A highly ingenious theory of immunity was suggested in 1882 by Elie Metschnikoff, who,

* See Vallery-Radot, *Louis Pasteur: His Life and Labors*, New York, Appleton, 1885, pp. 220–246.

starting with the well-known fact that the white blood cells are eating cells (or *phagocytes*) and readily devour yeast cells, bacteria cells, etc., made elaborate and important investigations tending to show that, in the struggle between man and microbe which may be said to constitute the essence of an infectious disease, the battle is really between the white blood cells and the microbes, after the latter have somehow secured entrance into the body proper, and especially into the blood vessels. Metschnikoff's theory of immunity is therefore known as the theory of phagocytosis. It has the merits of simplicity and picturesqueness; but, while doubtless containing much that is true, it fails at one of the most important points, namely, in explaining the persistence of immunity long after the disease is over except indeed on the somewhat too anthropomorphic theory that the phagocytes have become "trained" or "educated." It fails, also, to account satisfactorily for some of the remarkable phenomena afforded by blood-serum experiments, such as those now to be described.

Behring and antitoxic serums. — In 1892 an entirely new line of experiment was opened up by Behring and Kitasato in their work on diphtheria. It was discovered by them that the serum of an animal which had been made immune to the toxin of diphtheria was able, even in a test-tube, to neutralize or impair the virulence of such a toxin, and further that the serum of a non-immune animal was not able to do this. Clearly, then, substances exist in the serum of an immune animal which were not there before the process of immunization, and a good part of our present theory of immunity rests upon this fact. The process of immunization according to the serum theory may be described as follows: the microbe (or its toxin) irritates the cells of its host; these produce defensive substances or antidotes (antitoxins), which tend to neutralize the poison, or to inhibit the activity, of the microbe, or both. If we assume victory for the cells, we have temporary immunity or convalescence. Victory for the microbe means continued disease or death. If we may assume that the cells of the body continue to secrete more or less of the defensive substances, or that they remain for a long time peculiarly sensitive to even minute doses of the toxin in question, we can understand the persistence of more or less immunity. But these assumptions, while plausible and perhaps reasonable, are purely hypothetical.

Biologic products as cures and preventives. — The practical outcome of Behring's work has been of immense importance, especially in the cure and prevention of diphtheria. Patients suffering from this disease, and persons exposed to it, may and do have their own antitoxic serum reënforced by the antitoxic serum of the horse or other immune animal and thus are materially aided in their battle with the microbes. The process is as follows. Microbes of diphtheria are cultivated in a richly nutrient liquid which gradually becomes charged with their toxin. The liquid is filtered, and portions of the toxin-bearing filtrate are injected subcutaneously into horses, beginning with small doses and continuing until the animal is immune to large doses. Blood is then drawn from the immune horse, and the serum from this blood is found to contain diphtheria antitoxin in abundance. This serum is concentrated and carefully filtered and then used intramuscularly in mild cases and intravenously in more severe cases as a reënforcing remedy for persons actually ill with diphtheria, or as a preventive medicine by those who have been "exposed" to it. The results of the serum treatment have been universally most encouraging and successful.

Since the discovery of diphtheria antitoxin great progress has been made in the control of diphtheria. According to Dr. William H. Park of New York City, who has been a world leader in the conquest of diphtheria, the death rate from this disease in New York City in 1860 was approximately 100 per 100,000. In 1871 the incidence of diphtheria began to increase sharply, so that by 1875 the death rate had reached 280. For a time the number of deaths declined until the rate dropped to 130. In 1881, the death rate again rose to 260; in 1887, it was 200, and in 1894, the year when antitoxin was first used in the United States, the death rate was 155. With the use of antitoxin the death rate diminished considerably, although its virtual conquest was delayed until toxin-antitoxin was introduced to immunize children against diphtheria, and city milk supplies were pasteurized to prevent the spread of this disease through this medium. What a contrast it is to know that in 1931 the death rate from diphtheria in New York City was only 2.6 per 100,000 population.

Some indication of the value of antitoxin in the treatment of diphtheria can be obtained from the following data.

TABLE 6

DEATH RATE FROM DIPHTHERIA PER 100,000 POPULATION BEFORE AND AFTER THE USE OF ANTITOXIN

CITY	1885 1894 [1]	1895–1904 [2]
Berlin	99.3	29.5
London	48.5	38.8
Paris	64.1	14.9
Vienna	81.4	29.5
Baltimore	73.4	49.9
Boston	117.6	63.4
Chicago	142.9	51.3
New York	151.9	66.2

[1] Before antitoxin was used
[2] After antitoxin was used

In 1933 an analysis of the death rates from diphtheria for the 93 large cities of the United States, made by the *Journal of the American Medical Association* * showed that 25 cities had death rates from diphtheria that were less than 1.0 per 100,000. Among these were Baltimore, Chicago, Milwaukee, Newark, New Haven, Oakland, Philadelphia, and Trenton. Only 10 cities had death rates greater than 8.0 per 100,000 population, the highest rate being 12.0. Eleven cities did not have a single death from diphtheria in 1933. They were Duluth, Elizabeth, Hartford, Rochester, Salt Lake City, Seattle, South Bend, Spokane, Springfield, Mass., Syracuse, and Yonkers.

Our knowledge of diphtheria today is such that it is possible, theoretically at least, to exterminate this disease. Blessed with a ready means of cultivating and detecting the microbe responsible for the disease, from the nose and throat of a suspected individual, reënforced in our efforts of mastery over the disease by a life-giving serum — diphtheria antitoxin — the means are already at hand for the prompt detection and effective treatment of one of the worst scourges of childhood. But this is not all. Through the discovery of Bela Schick in 1913, a ready device was placed at the disposal of physicians, whereby the susceptibility or immunity of an individual to diphtheria could be easily determined. This is done by inoculating into the skin a very small amount of diphtheria toxin and observing whether a given reaction occurs. Furthermore, there is available today a means for rendering all susceptible individuals immune to diphtheria. This has already been

* *Jour. A. M. A.*, v. 102, No. 21, May 26, 1934, p. 1758.

TABLE 7

Biologic Products for the Diagnosis, Prevention, and Treatment of Communicable Diseases *

Disease	For Diagnosis	For Prevention	For Treatment
Smallpox		Vaccine virus	
Rabies		Anti-rabic vaccine [1]	
Bubonic plague		Bacterial vaccine	Anti-plague serum
Cholera		Bacterial vaccine	
Typhoid fever, Paratyphoid fever	Agglutinating serums for bacteriologic diagnosis	Bacterial vaccine	
Whooping cough		Bacterial vaccine [2]	Bacterial vaccine [2]
Tuberculosis	Tuberculin "O. T." for Pirquet or Mantoux tests		Tuberculins, "O. T.," "B.E.," "B.F."
Tetanus		Tetanus antitoxin	Tetanus antitoxin
Diphtheria	Diphtheria toxin for Schick test [3]	Diphtheria antitoxin Diphtheria toxin-antitoxin Diphtheria toxoid	Diphtheria antitoxin
Gas gangrene		Gas gangrene antitoxin	Gas gangrene antitoxin
Botulism			Botulism antitoxin [4]
Bacillary dysentery	Agglutinating serums for diagnosis		Anti-dysenteric serum
Anthrax		Bacterial vaccine	Anti-anthrax serum Normal bovine serum
Lobar pneumonia Type I	Agglutinating serums for diagnosis — Types I, II, III	Bacterial vaccine [5]	Anti-pneumococcic serum
Meningococcus meningitis	Agglutinating serums for Group determination		Anti-meningococcic serum
Scarlet fever	Streptococcus scarlatinae toxin for Dick test [3]	Scarlet fever toxin Scarlet fever antitoxin	Scarlet fever antitoxin
Anterior poliomyelitis			Convalescent serum[6]
Measles		Convalescent serum	Convalescent serum

[1] For use after infection has taken place and before development of disease.
[2] Still of unproved value.
[3] For determination of susceptibility.
[4] Not yet of therapeutic value.
[5] Still experimental.
[6] Convalescent serum is serum obtained from individuals recovering from a given disease, and presumably contains the immune bodies for that disease.

*Based in part on *The Commonhealth*, Mass. Dept. of Public Health, April–June, 1923.

accomplished in the United States on an enormous scale, through the use of toxin-antitoxin and more recently through diphtheria toxoid. Immunity to diphtheria is thus usually established, and whether or not it is present, can be readily determined by means of the Schick test.

Numerous other biological products are available today for use either in the prevention or treatment of disease, or for detecting susceptibility. Those commonly employed are presented in tabular view below. Specific mention should also be made here, of the availability of the Dick test for detecting susceptibility to scarlet fever; of the existence of scarlet fever toxin for immunizing susceptible individuals; and of the use of scarlet fever antitoxin in the treatment of the disease after it has developed.

The preceding table presents a list of the biological products now available and in use.

CHAPTER V

INFECTION AND CONTAGION: THE PATHS AND PORTALS BY WHICH THEY ENTER THE BODY

Infection, infectious substances, and infectious diseases. — In order that apple juice shall be fermented by yeast, microörganisms must somehow find access to it. But the normal apple is protected from the invasion of yeast both by its skin — a mechanical or structural defense — and probably also by specific properties of its living cells, which properties, though they are not understood, are recognized and described by the term "vital resistance." The skin of the apple must be broken and vital resistance overcome before yeast can make its way into either juices or tissues, successfully "infecting" them and producing those changes which we call fermentation. It may even be said that the apple is "hermetically sealed" by its skin, for no sound apple can be infected or fermented by yeast unless its body has been penetrated either by living yeast cells or else, what is yet an open question, by soluble and diffusible products of yeast.

The word "infection" (from *in* and *facere*) signifies "entrance" or, literally, "making into," and in sanitary science it means in the first place, a process, namely, the entrance into a living body, whether plant or animal, of something capable of producing disease. Contagion, as will be explained presently, is only a special kind of infection. The words "infection" and "contagion" are also used to represent the infectious or contagious material itself. From what has been said in the preceding chapters it is plain that infection of the human body is usually its invasion by parasitic microörganisms, each specific invasion constituting a specific infection; and the "infectious diseases" are those which are produced by such invasions. The term "communicable" is also much used for this group of diseases. In practice the word "infection," when used for infectious materials, is usually applied to living *materies morbi* capable of growth and multiplication in the body of the infected plant or animal and of transfer from one victim to another. Etymologically speaking, to be sure, it might be applied also to

inorganic matters such as metallic poisons — lead, copper, arsenic, etc. — or to organic but lifeless poisons — such as the venom of serpents, the vegetable alkaloids, etc. — introduced in any way into the living organism; but as these are doubtless also communicable (though rarely communicated), either term may be used at will, both being clearly inferior in descriptive accuracy to the term "zymotic," which, after all, is probably the most correct and comprehensive name for those diseases which are essentially attacks upon the plant or animal body by living ferments.

The skin and epithelia as structural defenses of the living body against the invasions of disease. — As the normal apple is protected by its covering or skin, so the normal living body is protected by its coverings — skin and epithelia — from the invasion of parasitic or fermentative microorganisms or their products. It is perhaps too much to say that the living body is hermetically sealed, and yet modern physiology teaches that one of the principal offices of the skin is protection against forces or substances acting from without, and that the cells of the more delicate epithelia covering the lung surfaces and the alimentary and genito-urinary tracts have as one of their specific duties a certain discriminating authority over the matters likely to pass through or to be absorbed by them. In somewhat more than a metaphorical sense, therefore, it may be safe to say that the living animal body is hermetically sealed against the invasion of matters proceeding from the environment. The phrase, once much used, which referred to any rupture of this seal as a "solution of continuity" undoubtedly referred to the same idea, and marks the recognition of the essential integrity of the body surfaces as one condition of health.

In order that any germ, whether parasitic or not, shall find entrance into the living body, it must be able somehow to pass through the ordinary defenses. In the case of the skin it would appear that an actual rupture must take place, as happens, for example, in a puncture, incision, bruise, or other mechanical injury. In the case of the epithelia, it may be that a similar passage by force is necessary, or it may be that the living cells which here line the surface externally are, so to speak, off their guard or for the time being actually facilitate an invasion which, from their delicacy, is here more easily effected. At any rate, it is easy to see that for the actual entrance of microörganisms into

the body proper an unusual and direct passage must somehow be provided.

It should not be forgotten that by "the body proper" is meant that portion of it enclosed within the skin and epithelia, the cavities of the alimentary canal and the genito-urinary tracts not being included, inasmuch as they are really portions of the environment merely passing through or dipping into the body-mass.

Infection by way of the skin. Invasion by force. — The processes of infection by way of the alimentary canal and the genito-urinary tract are typical of a large class of the more obscure infectious diseases. There is, however, another and commoner path by which microorganisms obtain entrance into the body proper, and that is directly through the skin, the diseases to which they give rise being known as "wound" diseases. Many of these are familiar, as, for example, the results of simple punctures made by small foreign bodies such as pins, needles, "slivers," and the like. When these carry in with them microorganisms capable of setting up fermentation or inflammation, the infection thus produced may be either local or general: in the former case leading to the conditions familiar in such unimportant local wounds as those mentioned; in the latter to septicemia, or dangerous blood poisoning, a kind of fermentation of the whole body. Occasionally it happens that a wound made by a sliver or some other ordinarily insignificant object, such as a needle or a bee sting, is followed not merely by the usual local inflammation, but by a far more serious and extensive injury and even by speedy death. It is supposed that in these cases either the infection was of an unusual and severe type — by which is meant that the microorganisms were unusually abundant or of some unusually virulent species — or else that the vital resistance of the cells and tissues of the victim happened to be poor in kind or at a low ebb, so that even ordinary microorganisms met with specially favorable conditions. In a word, either the infection was unusually powerful or the patient was unusually susceptible. It is, of course, possible to conceive of a third condition resulting from an unfortunate coincidence or combination of the other two.

Wounds and the diseases of wounds. — The punctures and other simple infections by way of the skin just described belong in the same class with more serious interruptions of continuity such as gun-shot wounds, compound fractures, abrasions and the

like, among which must be classified as of the highest practical importance surgical operations such as excisions of tumors, amputations, the tying of arteries, etc. In these cases the bullet, the surgeon's or dissector's knife, or other foreign body of relatively large size, may readily be a vehicle for the germs of infectious disease. It has already been pointed out how the classical inductions of Lister and his application of the germ theory and its corollaries to this class of diseases has led to results of the first importance in this direction, namely, to sanitary or aseptic surgery.

There is one disease of wounds particularly interesting, for various reasons, to the sanitarian as well as to the surgeon, namely, *tetanus* or "lockjaw." It had long been known from observation and experience that certain punctures or incisions, especially those made by the entrance or laceration effected by dirty foreign bodies, were not infrequently followed by a peculiar condition of the patient in which tetanic muscular spasms were a prominent feature, when, in 1884, Nicolaier isolated from garden soil a bacillus capable on inoculation into mice and rabbits of producing a similar disease. Further investigations have confirmed the discovery, and the natural history of the *Clostridium tetani* is now well known. It is frequently found in the earth and it is widely distributed in nature. It is anaërobic, *i.e.*, it thrives best in the complete absence of oxygen. Cultivated in bouillon, it produces a powerful poison (toxin) which, even in the absence of all living bacteria, is capable of producing typical tetanic convulsions. A substance apparently identical with it has been separated from the muscles of patients dead of tetanus, and this substance, when injected into the lower animals, produces in them tetanic spasms. It may be added that an antitoxin capable of neutralizing the toxin of tetanus has been prepared and used.

The importance of the bites and stings or other punctures of the skin by insects, which has long been recognized theoretically, has received fresh emphasis and attention, owing to the results of investigations upon the widespread disease known as malaria, and the establishment of the fact that it is transmitted by the bite of the Anopheles mosquito. At the beginning of the twentieth century evidence was obtained through the efforts of American and Cuban investigators in Cuba—Reed, Carroll, Lazear, and Agramonte — at great personal risk, and with admirable courage, that yellow fever is similarly transmissible by mosquitoes — the

Aëdes egypti, formerly known as the Stegomyia calopus — and not readily, if at all, by infected bedding or other lifeless materials.

Flies have been proved to be vehicles of infection, especially of typhoid fever and other filth diseases. Lime scattered over excrement in latrines has been observed on the feet and legs of flies crawling over food set out on kitchen tables, as was demonstrated in the army camps in Florida during the Spanish-American War. If lime can thus be carried, there is no reason why microbes also may not be carried to food or drink. Again, in the case of African sleeping sickness, it is through the bite of a specific fly that infection is transmitted. Similarly, if the necessary conditions are appropriate, the bites of other insects or animals may result in disease. The bite of a rabid dog may result in rabies; that of an infected body louse, in typhus fever; that of an infected rat flea in plague; and that of appropriate infected mosquitoes, in dengue fever and filariasis.

Infection by way of the alimentary canal, lungs, and the genito-urinary tracts. — The alimentary canal being in free connection with the environment and really a portion of it, is naturally subject to invasion from numerous sources by various microorganisms and similar extraneous matters; and the same thing is true of lungs and genito-urinary tracts, though perhaps in less degree. The alimentary canal, moreover, is ordinarily well stocked with food materials for microörganisms, and although the gastric juice exerts an unfavorable influence upon most of them, it may be said that, on the whole, the warm and well-fed alimentary canal, particularly the small and large intestines, affords an excellent breeding ground for certain bacteria. But if bacteria multiply enormously in the lower alimentary canal, they do so at the expense of materials found therein, and in the course of their multiplication must produce various substances of the nature either of by-products or excreta; and some of these may conceivably be harmful either to the guardian epithelia lining the intestinal tract or to the tissues in general, if once they are absorbed and distributed by the circulation. Similarly, microörganisms grow freely within the genital tracts, and feeding upon the exudations or secretions there found may multiply enormously, with the consequent production of deleterious substances which may damage either the lining epithelia or, when absorbed, other tissues of the body, near or remote. Moreover, in both these cases the paralysis or destruction of the

guardian epithelia may produce actual solution of continuity, which may allow either the microörganisms in question or their poisonous products to find ready entrance into the body proper. The bacillus of diphtheria, for example, works precisely in this way. Numerous other infections of the respiratory system occur, such as scarlet fever, measles, whooping cough, the common cold, influenza, pneumonia, tuberculosis, etc., which result in many cases of disability and even death. Here, too, disease may be due either to the penetration of the protective mucosa by the responsible organisms directly or to their toxic products.

In the case of Asiatic cholera, there appears to be first an invasion and then a genuine and extensive fermentation of the contents of the alimentary canal, with an enormous multiplication of the microorganisms concerned, so that these can readily be detected in large numbers in the bowel discharges. At the same time the characteristic poison or toxin of Asiatic cholera is liberated, and its absorption through the walls of the alimentary canal gives rise to constitutional symptoms characteristic of the disease and indicative of profound disturbance of the body proper, such as vomiting, fever, sweating, and delirium. In these cases, as will be observed, it is not the germs themselves, at least in the first place, which penetrate into and ferment the body itself. It is rather by attacking the frontier, there and then setting up their own peculiar fermentations, and producing poisons which are easily absorbed, that these microorganisms first do their harm and open the way for themselves or other germs to enter into the body proper.

Man and other animals; the principal primary sources of infection. — We have now considered somewhat briefly the portals of entrance of infectious materials into the body proper, and have hinted at some of the vehicles of infection. Before dwelling long upon these it will be well to consider the original sources of infectious materials in the environment. Once we have determined the sources of infections, it will be comparatively easy to discover the avenues of communication and the vehicles by which they travel.

It was formerly supposed that the earth and various other nonliving materials were prolific original sources of infectious disease, or in other words, that the germs of disease not only exist but thrive and multiply in the earth. It was thought, for example, that the microörganism of typhoid fever passes a portion of its life and

undergoes a necessary portion of its development in the soil, especially in filthy soil, and similar ideas were held in regard to other infectious diseases. Doubtless the reason for this opinion was to be found in the fact that certain animal and vegetable parasites had been known for a long time to spend one portion of their lives in or upon some plant or animal other than, and often lower than, their most conspicuous host. This is true of the tapeworm, the *Trichina*, the blight of barberries, and many other parasites. The progress of inquiry, however, has not confirmed these ideas for the ordinary communicable diseases, except in special cases (such as that of *tetanus*). It has been said that some still hold to the idea in the case of typhoid fever; but this idea is not sound. Every case of typhoid fever arises rather directly from an antecedent case, and in this way only. The typhoid bacillus can unquestionably *live* for some time in nature, though apparently with diminishing virulence, and in diminishing numbers; but under ordinary conditions of temperature, dryness, and sunlight, its prolonged survival, and especially its multiplication outside the body, does not occur. A similar statement may be made in the case of many other communicable diseases, and we may safely say that for the most part man and other animals are the original sources of disease.

The amazing revelations of the rôle played by mosquitoes in the conveyance and the development of malaria are now a glorious chapter of sanitary history. Here also was a disease long associated with swamps and mysterious "miasms." It has been demonstrated, however, that it has its source only in animal bodies, for the malarial parasite comes only through the bodies of men and mosquitoes, and not through bad air or the environment in general.

Man and other animals, and especially their excreta, the principal primary vehicles of infection. — If it be true that man and other animals are the principal original sources of infection, it must follow as a matter of course that their excreta and secretions are the principal original vehicles. Physiology teaches that the material output of the animal body consists of discharges from the alimentary and genito-urinary passages and from the skin — the nose and lungs being regarded as branches of the alimentary apparatus — and accordingly it is these discharges which must be the principal original vehicles of communicable disease from its place of origin to the environment. Diseases have, in the past, often been roughly classified according to their place of origin and the vehicles

by which they are conveyed. An important class of maladies known as "diarrheal" diseases is directly attributed to infections from the bowel discharges. Typhoid fever, Asiatic cholera, dysentery, and diarrhea, are the most important members of this class. Of equal or even greater importance are those diseases known as "eruptive" and respiratory diseases, which are readily scattered by the secretions from the nose and throat. To this class belong some of the worst diseases that afflict the human race, such as smallpox, diphtheria, scarlet fever, measles, chicken-pox, tuberculosis, and many more. Since the infectious material is in this case poured out upon the surface of the body, it is readily transferred by direct contact to the fingers and thereby to the mouths, or, when carried by the air in the form of a mouth or nose spray, to the noses and lungs of other persons. Hence the term "contagious" diseases, which is especially applied to this group. Some of these diseases which affect the mouth, throat, or lungs, like diphtheria, scarlet fever, and tuberculosis, may also be conveyed to susceptible individuals by means of the sputum or saliva through the agency of food contaminations.

The other secretions and excretions, such as the urine, the breath, and the sweat, are not usually associated with the transmission of disease. The expired air, formerly so much dreaded by those who watched at the bedside, is practically germ-free. The reason for this is that the moist, spongy lungs act as an efficient deterrent, and not only refuse to yield up microorganisms to the expired air, but even detain organisms arriving in the inspired air, so that the outgoing breath of a patient is, from the bacteriological point of view, actually purer than the inspired air. The urine, however, in the case of some typhoid carriers, may be a ready vehicle for the microbes of typhoid fever.

Earth, air, water, milk, and other foods, and animals the principal secondary vehicles of infectious disease. — If the secretions and excretions are the principal original vehicles of infection they are by no means the only vehicles, for they may readily mingle with and transfer their burden of infection to almost any substance in the environment. From the skin the surrounding air may first become infected and then move on, laden with disease, so that disease — or rather its germs — may literally be borne on "the wings of the wind." This is true only in the case of droplet infection resulting from coughing, sneezing, and loud speaking. Likewise,

sputum from the mouth, or discharges from the bowels, may be imperceptibly mingled with a stream, so that a cup of cold water — the time-honored symbol of purity and charity — may contain unseen and unsuspected the germs of deadly or disgusting diseases. Or, again, the earth impregnated with human secretions and excretions may be dried and pulverized, and as dust serve to infect human throats, wounds, or abrasions, or the food of man. Clearly, if animal life is the principal source of infection, and the secretions and excretions of animals are its principal vehicles, these are only too likely to find suitable substances in the environment with which they can mingle, and to which they can convey a portion at least of their burden of infection.

We have already seen that insects may become the bearers of infection, a subject which is discussed in greater detail in subsequent chapters. In the chapters that follow immediately we may turn to a detailed consideration of several other of the most important and most common vehicles of infection, namely, dirt, dust, air, sewage, water, ice, milk, raw foods (such as oysters and salads), and the like, and the ways in which these can be protected or purified.

CHAPTER VI

DIRT, DUST, AIR, AND DISEASE. THE LIVING EARTH

The experience of the race has shown that one of the most effective vehicles of disease is dirt. The word "dirt" appears to be derived from an old Saxon word *drit*, meaning *excrement;* but the modern form of the word "dirt" has taken on a more extended and less definite meaning. As ordinarily used it may be the synonym of dust, soil, filth, or almost any form of uncleanliness, whether such uncleanliness imply the presence of infection or only that of pollution. Still it can hardly be denied that even at present the word "dirt" signifies something distinctly more filthy than do the words "earth," "soil," or "dust." It is easy to see in the origin of the word the reason for this, and after what has been said in the preceding chapters concerning the primary sources of infection and the efficiency of secretions and excrement as vehicles of disease, no surprise need be felt that dirt is regarded with suspicion by all intelligent and well-informed persons.

Clean earth and infectious dirt. — Unquestionably the general fear of dirt among the intelligent is not in all cases discriminating. There are forms of dirt which carry with them very little of danger, and a certain recognition of this fact is shown in such expressions as "good clean earth." It appears to be true that while it is the earth that is most often associated with the idea of dirt, it is ordinarily only the surface of the earth which is thus looked upon with suspicion and aversion. One reason for this probably is that the surface or loamy layers of the soil are not infrequently sticky and suggestive of organic matters, while the subsoil directly below the loam layer is generally more obviously mineral in its character and often clean, *i.e.*, not sticky or "dirty." As a matter of fact the loamy layer so called is, in truth, richer in organic matters, and besides often containing innumerable earthworms is crowded with the bodies of microorganisms. The earthworms by their plowing actions, which Darwin has so admirably worked out, are constantly turning over the upper layers of the earth, carrying from the surface into the lower strata organic matters, and from below to the

surface the more mineral subsoil. It follows, therefore, that not only is the surface of the earth contaminated by excrement of various kinds that falls upon it, but also, through the agency of earthworms, a considerable portion of the earth just below the surface, and especially, no doubt, the loamy layer already referred to.

Accordingly, if we desire to define and classify the terms already used, we shall say that *earth*, broadly speaking and for the most part, is essentially mineral in character and clean in condition because free from any considerable amount of organic matter. It is also, therefore, ordinarily free from infection — uninfected as well as unpolluted. *Soil, i.e.*, the surface layer of the earth, may be clean, and may be and ordinarily is fairly free from infectious materials, but inasmuch as it is exposed to contamination by dirt, *i.e.*, excrement, and is being continually worked over by earthworms, it may be and usually is more or less polluted or contaminated with organic matter. It may or may not be infected. *Dirt* in the original and most exact sense is simply excrement, but in the more ordinary use of the word is *soil, i.e.*, the surface layer of the earth.

The living earth. — It is one of the most marvelous revelations of bacteriology that the earth, long regarded as the type of lifelessness, is in fact, at least in its uppermost layers, teeming with life. Not only do many mammals, birds, reptiles, insects, and worms have their homes in the earth, but also vast hosts of microörganisms, more abundant by far than the grains of sand upon which they dwell. A single gram of garden soil may contain millions of microörganisms, and much of the softness and stickiness of moist loam is probably due to the presence of such numbers of soft protoplasmic bodies. Thus it has come to pass that we are no longer at liberty to speak or think of the earth, at least in its upper layers, as dead and essentially mineral, but must regard it instead as highly organic and quivering with life.

Earth as a vehicle of disease. — The earth is not only rich in germs, but may contain among these some that are pathogenic or disease-producing. Reference has already been made to tetanus as caused by specific microbes found in the soil, and these are especially interesting, inasmuch as they appear to lead regularly a saprophytic rather than a parasitic life. In this respect they (and a few others) differ from most pathogenic microbes, which for-

tunately do not, under ordinary conditions, appear to thrive (though they may continue to live for a long time) outside the plant or animal body. The bacteria responsible for gas gangrene, botulism, and a specific type of diarrhea are also found in the soil. It is interesting to note that all of these bacteria form spores which enable them to survive in nature for exceedingly long periods of time.

Dust and disease. — Dust is pulverized soil or pulverized dirt, and only rarely pulverized and pure earth. It is therefore, as a rule, rich in bacteria, and may or may not contain disease germs. Inasmuch as it is the surface of the earth which is ordinarily dried, pulverized, and lifted into the air, it is easy to see that pollution of any kind, deposited upon the soil, sputum, and other organic matters cast off by animal bodies — such as scales from the skin, bits of hair, dandruff and the like — as well as the possible combination of all these things with dirty water to make sewage, may when dried on the surface of the earth be also readily pulverized and lifted into the air as fine particles or motes of dust. At first sight, dust of this character might be supposed to be necessarily dangerous and even deadly, and under favorable circumstances it is possible that diseases may in fact be transmitted by dust; but, on the other hand, it should not be forgotten that there are certain compensating circumstances which tend to diminish the dangers of disease from this source. The unfavorable conditions to which microörganisms are exposed in dust, namely, desiccation, the germicidal action of sunlight, unfavorable temperatures, and the lack of proper food, undoubtedly destroy many of them and weaken others, but, in spite of these various fortunate conditions, it still remains true that dust must always be regarded by the sanitarian as potentially dangerous, not only because of the mechanical irritation of the delicate mucous membranes of the throat and other respiratory passages caused by the inorganic particles of which it is partly composed, but also because of its possible association with disease germs, especially those that give rise to pyogenic or pus infections, certain respiratory diseases like sore throat and the common cold, and perhaps others on which specific information is not yet available.

The atmosphere as a vehicle of disease. — From the earliest times the atmosphere has been regarded with suspicion as a vehicle of disease. Miasms, pestilential vapors, and various mysterious

and unseen influences have been regarded as readily conveyed by the atmosphere, and obscure or occult effects not comprehended or else misunderstood have been attributed naturally enough to the omnipresent and always-moving atmosphere. It is one of the merits of the germ theory of disease that it enables us to comprehend much more clearly than ever before the true nature of these supposed atmospheric influences.

The prevailing viewpoint today is that air in itself is not dangerous and is not a true vehicle of disease. Cases of scarlet fever and typhoid fever can be treated side by side in a modern hospital without any risk of cross-infection, if adequate precautionary measures, through the use of proper technique to prevent such transmission of disease, are taken. It is only under special and unusual cases, when the air is laden with the spray from the mouth or nose, or with infected dust, that it becomes a vehicle of disease. But even in such cases the part which the air plays is only incidental. Disease transmission in this way is essentially by contact infection rather than by the atmosphere.

Microbes of the air. — The number of microbes in the atmosphere varies greatly. In a dust-storm five feet above the surface of a macadamized street the number found in ten liters of air was 200,000. Quiet air is usually relatively free from them (sewer air, for example, being often nearly or quite destitute of microbes), and the same is true of the atmosphere at high altitudes and in mid-ocean. Even the expired air of the human lungs is quite free from germs.

It is impossible to conceive of any other source or sources of disease in the atmosphere than microbes. On the other hand, there is no difficulty in supposing that the ground air, rising and mingling with the ordinary atmosphere, especially in periods of low barometer; the gaseous exhalations of marshes, volcanoes, and the like; the results of decomposition of dung-heaps, filth, and other masses of decaying organic matter; the inhalation of other foul or poisonous gases, such as those arising from oil refineries, smelters, illuminating gas and other sources of carbon monoxide, may, under certain circumstances, act as unfavorable environmental conditions and reduce the vital resistance to such a point that disease which would otherwise have been absent, occurs. This simple view probably includes all or nearly all of the facts relating to the atmosphere as a source of disease and probably suggests the true

explanation of diseases supposed to be due to miasms, pestilential vapors, atmospheric and telluric influences, and the like. Even malaria which once was a puzzle to sanitarians is due not to any peculiar evil quality or disturbance of the atmosphere, such as the word implies, but rather to specific parasites conveyed by certain mosquitoes capable of moving in or through the air. Malaria has often been called *paludism* or swamp fever; but according to the modern view it is not swamp air, but swamp insects (mosquitoes), which under favorable circumstances transport the germs of *paludism.*

Filth diseases. The pythogenic theory. — The principles which have been laid down in the preceding chapters enable us to take up with regard to filth diseases a somewhat different view from that held in the third quarter of the nineteenth century. The term "filth disease" was at that time used with the idea that filth might be not only a vehicle, but an actual breeder or generator of disease. This view even reached the dignity of a theory bearing a special name — the "pythogenic" theory — which is closely associated with the name of Murchison. According to Murchison, filth was dangerous not merely because it was a vehicle of disease, or an unfavorable condition, but also because it was a *source* of disease, the supposition being either that specific disease germs could be generated *de novo* from other germs in filth under favorable circumstances, or that at least germs capable of producing disease found in filth the conditions for their more perfect development, some even requiring residence for a time in filth in order to reach their full maturity. In regard to typhoid fever, for example, it was held that the microörganisms of the disease required a stay, longer or shorter, in the earth or heaps of filth, and only after such a period attained their natural and dangerous development.

The modern theories of filth and its dangers are very different from these. Filth is first and always a convenient vehicle of disease; but as a rule, in temperate climates, it is probably nothing more than this unless it be also a depressing, or unfavorable, "predisposing" condition. The earlier view which saw in filth a necessary phase in the life history of certain pathogenic microörganisms has now been abandoned. The most natural and the most favorable means for the conveyance of disease germs is that which is quickest and most direct, namely, contagion, or the transfer directly from one individual to another without the interposition of the earth,

the atmosphere, or other extraneous influences. Contrary to Murchison's view, the longer the journey, and the more the time spent in making the journey from patient to victim, the less is the likelihood of the successful transmission of the disease. The interposition of filth or earth or air or water doubtless tends in most cases to the diminution of danger, owing to the unfavorable conditions of one sort or another encountered by the germs *en route.*

Filth is looked upon by the sanitarian of today, therefore, as dangerous chiefly because it may contain the more or less attenuated germs of disease, and not so much as formerly because it may be a "breeding place" for such germs. It is a vehicle rather than a source.

The philosophy of cleanliness. — From what has now been said, it is easy to perceive the reasons for the modern philosophy of cleanliness. Dirt is dangerous, not because it is "of the earth, earthy," but because it is too often *drit* or excrement; and the love of cleanliness or the abhorrence of dirt, which is becoming established in all highly civilized peoples, is doubtless a resultant of the dearly bought experience of the race, which has shown that dirt is dangerous and therefore to be dreaded. Cleanliness, or the absence of dirt, is not merely an aesthetic adornment — though doubtless an acquired taste; it is above all a sanitary safeguard, the importance of which has been learned by hard experience. In other words, to be clean is in a measure to be safe from disease; and cleanliness applies not only to the person but extends also to the personal environment and especially to the food supply, the water supply, the milk supply, etc.

Probably the greatest sanitary step ever taken by the race was the application of high temperatures to the preparation of food, *i.e.*, cookery. There is very little doubt that far more important than any increase in the digestibility of food effected by cookery is the destruction of parasites, visible and invisible, within it thus brought about. Charles Lamb was probably right in attributing the love of cookery to the improvement in the flavors of food which it occasions, as is described in his well-known version of the discovery in the case of roast pig; and yet there is every reason to believe that the sanitary improvement wrought by the discovery of cookery was even more important than either the gustatory or the nutritive improvement. It is difficult to see how infection could have been otherwise than very common and very disastrous

before the invention of cookery, for even to this day uncooked food forms one of the principal vehicles for the conveyance of parasites and disease germs.

Personal *versus* public cleanliness. — It follows as a matter of course that personal cleanliness is more important than public cleanliness. In other words, that the avoidance of personal filth is far more necessary than, for example, is cleanliness of streets, dooryards, alleys, and the like. And yet, as is pointed out later, public supplies are public dangers. If the public water supply, for example, be infected, no matter how scrupulously clean the residents of a city may be in respect to their persons, they will run very serious risks of disease if they drink from it. The same thing may be said of the public milk supply; and nothing is more impressive to the practical sanitarian than to witness an epidemic of typhoid fever in a wealthy and well-cared-for quarter of a city, where the inhabitants are personally clean, the houses are unexceptionable, the plumbing perfect, the drains in good condition, the tableware and linen spotless, and yet typhoid fever is present perhaps in nearly every family because of a polluted and infected milk supply or water supply. It must never be forgotten that the sanitary chain is no stronger than its weakest part, and that no matter how clean and wholesome all other conditions may be, if there is one point from which the germs of infectious disease may find admission into the body, danger may be imminent. Nothing is more instructive than to discover cities or towns in which great complaint is made of filth in the streets — from which, after all, comparatively little danger is likely to come — while an impure water supply or milk supply is being used with absolute confidence, or blindness, or ignorance.

Public drinking cups and their dangers. — The march of sanitary progress has brought home clearly the grave dangers that lurk in the use of the common drinking cup. The various pathogenic microbes that are found in the saliva and sputum, especially those responsible for the so-called respiratory diseases, may be transmitted from person to person in this way. What has been said about drinking cups as a potential vehicle of disease germs, applies in a measure to communion cups, "roller" towels, razors and shaving brushes in barber shops, and unclean dishes, spoons, etc. Sanitary fountains have been devised and are in use in many places thus doing away with the public drinking cup, and in so far

as they are successful in preventing contact between the lips of the user and the orifice of the bubbler, thus protecting the bubbler from pollution with the washings from the mouth, they deserve the warm commendation of sanitarians. The arrangement by which this is accomplished is very simple, and for use in public places, schools, institutions, and the like, it is a great sanitary safeguard. The common drinking cup, wherever found, must be regarded as a sanitary abomination and should not be tolerated any longer.

Cleanliness, asepsis, and antisepsis. — Inasmuch as dirt is richly laden with microörganisms — the agents of fermentation, putrefaction, and decay — it is plain that the absence of dirt, or cleanliness must go far to prevent these processes. It is clear, for example, that punctures of a clean skin made by instruments absolutely free from organisms cannot convey infection; that the knife of the surgeon if absolutely clean cannot cause "dissecting wounds"; that cookery of foods must tend to defer their decay: in short, that absolute cleanliness is equivalent to asepsis, and partial cleanliness is an antiseptic corresponding in efficiency to its extent. This is now so fully recognized that dirt is today regarded as the principal foe of the surgeon; and probably the cleanest rooms that have ever been known either in modern times or in the past, are the operating rooms of the hospitals of today.

In certain industrial pursuits experience has taught a similar lesson. By drawing milk from healthy cows with extreme precautions as to cleanliness, it has been possible to keep it sweet (if adequately refrigerated) during the whole period of a trip from Boston to Peiping, China. If, furthermore, the milk is heated (pasteurized) before being refrigerated, its keeping qualities are increased and its safety from disease-producing bacteria is assured. Various other dairying processes are also favored, if not conditioned, by cleanliness; canning and preserving are carried out far more successfully if done with scrupulous regard for cleanliness; and it is no exaggeration to say that in all human affairs cleanliness — which means the exclusion or destruction of germ life — is the keynote of successful sanitation.

CHAPTER VII

SEWAGE AND EXCRETA AS VEHICLES OF DISEASE, AND THEIR PROPER DISPOSAL

The disposal and disinfection of excreta. — Since there is reason to believe that the excreta of man and other animals are the principal original vehicles of infection, one of the first problems of sanitation is the safe disposal and disinfection of excreta. Various devices for the disposal of the wastes of animal life have had their day, but only two need now be mentioned, viz., the "dry-earth" system and the "water-carriage," or "sewerage," system. The former was at one time in high repute, and in some cases, as in farmhouses, country-houses, and villages, is still useful, especially if water is scarce or difficult to get. It is open, however, to the grave sanitary objection that although dry earth deodorizes well, it does not necessarily disinfect; while on the practical side the system is much less convenient than disposal by water-carriage. The introduction of running water for other purposes, even into farmhouses and villages, has also greatly favored disposal by sewerage.

Nevertheless, a considerable portion of the population in the United States, especially those people living under rural conditions or in the unsewered sections of cities and towns, is still dependent on methods of excreta disposal without the aid of sewers. As recently as 1934, it was estimated that 60 per cent of the population of the United States was still unprovided with sewers. Of approximately 70,000,000 people in the United States living in communities of 2,500 or more, *i e.*, urban communities, about 50,000,000 have public sewerage facilities. The consideration therefore of the sanitary methods of excreta disposal on the farm and in unsewered communities becomes a matter of primary sanitary significance, since there is abundant evidence which shows that the typhoid and intestinal disease rate in a community is directly related to the extent to which a sanitary system of excreta disposal has been introduced.

The ways in which disease may be spread from improperly dis-

posed excreta are numerous. Flies particularly may be vectors of such infections, and domestic animals like chickens, cats, dogs, and pigs may play their share. Furthermore, the ground in the vicinity of an insanitary privy soon becomes thoroughly polluted with fecal material, and such conditions are especially appropriate for the transfer of hookworm infection under suitable climatic conditions. In addition, under such conditions, infection may be carried for considerable distances over the surface of the earth by heavy rains and surface run off, so that wells and streams may become readily polluted and infected.

Excreta disposal in unsewered communities. — The simplest method of excreta disposal on the farm and in the unsewered community is the *privy*. Various types are in use, some of which are satisfactory, and others which are not. The *privies* commonly employed are (1) *the surface or ground privy;* (2) *the pail privy;* (3) *the earth pit privy;* (4) *the concrete vault privy;* (5) *the septic privy;* and (6) *the chemical closet.*

All privies should be equipped with suitable housing, properly ventilated and protected against flies, rodents, and domestic animals. The door to the privy should preferably be self-closing, and all seats should be provided with self-closing covers.

The *surface or ground privy,* which is still employed extensively, is decidedly unsatisfactory and should not be recommended. In this type of privy, the excreta is deposited on the ground, the storage space is usually inadequate and the protection against surface washings, domestic animals, flies, and rodents, is invariably unsatisfactory. Accordingly, such a privy represents a menace to health and should be replaced by a type conforming to modern sanitary requirements.

The *pail or can privy* is likewise unsatisfactory from a sanitary point of view and is therefore not recommended. This privy is also a surface or ground privy, the excreta being deposited in galvanized iron pails about 15 inches in diameter and 15 inches deep, instead of on the ground. The pails are water-tight, so that theoretically at least, there is no danger of soil pollution. Although the pails rest on a wooden floor, and are protected at the rear of the privy by a tight-fitting door, so that flies and animals are not supposed to have access to their contents, actually such ideal conditions are rarely found. The tight-fitting door gets out of order, or the scavenger forgets to close it, and the pail privy becomes as bad and

perhaps worse than the ground privy. Furthermore, if the scavenger is irregular in his service, as sometimes happens, the pails overflow, and a noisome, dangerous condition is created. Even when the scavenger service is satisfactory, the full pails must be handled, emptied, cleaned, and sterilized. Such complete and satisfactory service is difficult to obtain regularly. As a result of the various shortcomings described, the weight of sanitary opinion today is definitely opposed to the use of the pail or can privy.

The *pit privy*, properly constructed and operated, is very satisfactory, and as it is also inexpensive, this type is recommended for use especially on the farm. It consists of a pit about three feet square and five feet deep, constructed away from the well and above the ground water table. The privy house is located directly over the pit, suitable precautions being taken to provide ventilation and to prevent access of flies. The inside of the pit is lined with boards or more suitable sheeting, to a depth of about 18 inches below the surface of the ground. The lining extends above the ground about 6 inches, thus forming a curb against which earth or sand may be banked in order to prevent the rain water from passing directly into the pit. In this way, the excreta deposited in the pit is allowed to lose its moisture by draining and drying, and becomes relatively inoffensive. Odors can be diminished still further by covering the accumulated excreta occasionally with a shovel full of lime or sand.

When the pit is filled to within 18 inches from the surface of the ground, the privy house must be moved and the pit filled in with earth or sand. A fresh pit is dug, and the privy house is placed directly over it with all the precautions noted above. A pit privy may be in use for three to five years before the pit has to be filled and the privy moved. Since the contents of pit privies are rarely handled; since adequate precautions are taken to exclude flies, rodents, domestic animals, and rain water; since the contents of the privy undergo gradual mineralization and finally become innocuous; and since the pit privy is inexpensive to construct and easy to operate in a sanitary manner, this type of privy is therefore recommended.

The *privy vault* is identical with the pit privy except that the pit is lined with concrete, and the privy house is provided at the rear with a water-tight hinged door that fits directly over the vault. This type of privy is used extensively for rural schools and where

the privy is close to a water supply. When the vault is full or nearly full, the contents must be removed and disposed of by burial in shallow trenches in the field or in some other satisfactory way. This type of privy is not as satisfactory as the pit privy. The vault must be cleaned at least once a year; the contents do not become dry and inodorous; difficulty is encountered in maintaining fly tightness; and considerable expense and dissatisfaction are experienced with the scavenging service that is required.

The *septic privy* is essentially a septic tank, but is used in some instances where a water-carriage system of excreta disposal is not available. It consists of a water-tight tank, made frequently of concrete, and divided by means of partitions into two or three compartments. The tank is filled with water and the privy house placed directly over the opening at one end, care being taken to make all joints fly-tight and to provide adequate ventilation. As the septic privy may become a breeding place for mosquitoes, all ventilators must be screened effectively, seat covers must be kept in place, and kerosene or other suitable oil should be added to the contents once a week during the mosquito breeding season. About two pails of water should be added to the tank daily for every seat in use. As the decomposition of the organic matter in the septic privy is accomplished by means of bacteria, disinfectants or germicides should not be added. If a septic privy operates properly it will require cleaning only about once every five years. A cleaning period as short as six months may be found necessary, however.

The tank in the septic privy is usually rectangular in shape, the width being 0.4 to 0.6 of the length. It is provided with a manhole for cleaning purposes and has an overflow which discharges the excess digested liquor into a long tile pipe with open joints, embedded in cinders or other porous material at a depth of 12 to 18 inches from the surface of the soil. This material drains into the soil, and if clogging does not occur, is purified by oxidation.

The septic privy may serve groups varying in number from those found in one family to those employed in a mill or factory. The smaller tanks never have a working capacity of less than 200 gallons, and the depth of sewage in such cases is never less than three feet. Larger tanks have greater working capacities, but the depth of sewage does not exceed five feet. Ample space must also be provided above the water level in the tanks for the formation of scum, and this in turn should be broken up frequently by me-

chanical means, in order to permit the solids to settle to the bottom of the tank and undergo anaërobic decomposition. When the septic privy is cleaned, the sludge must be removed and disposed of by burial or burning, or in some other way, equally satisfactory.

The *chemical closet* is the only device that can be employed indoors where a water-carriage system of excreta disposal is not available. It was introduced in 1912, but its prohibitive expense has thus far limited its use to rural schools and factories. A form of chemical closet is available also for family use, where expense is not an important item.

The chemical closet depends for its effectiveness on the liquefaction and disinfection of the excreta by means of caustic soda. The strength used is in the proportion of 25 pounds of caustic soda to 15 gallons of water. This is prepared outside of the chemical closet and is introduced in solution form.

The commode type of chemical closet, which may be used by a small family, consists of a metal container usually enameled in white and having a capacity of ten gallons. To this container a small charge of caustic solution is added. The container is provided with an ordinary toilet seat and is vented by means of a 4-inch pipe above the roof. The container must be emptied about once every week. Since the distance between the contents of the container and the toilet seat is rather short, great care must be exercised to avoid serious skin burns. A mild acid like vinegar, or lemon juice, may be used as an antidote in such cases.

Usually, however, chemical closets serve larger groups so that the commode type is not employed. A tank having a capacity of 125 gallons for each bowl is commonly employed. The tanks are cylindrical in shape, being about four feet in length and 28 inches in diameter. The tank is made of pure iron or of copper bearing steel, and all seams are welded electrically. The tank is also dipped in hot, asphaltic enamel in order to make it corrosion proof. It is then put in place, connected with a ventilating duct and toilet seat, and charged with the caustic solution mentioned above. A charge of 25 pounds of caustic to 15 gallons of water will suffice for a 125-gallon tank for a period of 6 to 9 months.

While the tank is in operation care must be exercised to bring the alkali solution into intimate contact with the excreta. This is accomplished by means of an agitator, the handle to which is

located in the toilet compartment. The contents of the tank must be agitated at least once a day.

When the tank is full, it is emptied by opening a valve and allowing the contents to flow directly into a seepage pit especially prepared for this purpose. The seepage pit should have a capacity equal to twice that of the tank, and should be entirely free of broken stone, cinders, or other objects. A tight-fitting, strong cover should also be provided, capable of preventing accidental falls into the pit. Where a seepage pit is not available or cannot be employed the contents of the chemical closet must be removed in water-tight containers, and disposed of by burial or burning, or by use as a fertilizer.

After the tank is empty it is flushed with fresh water, the outlet valve is examined and repacked if necessary, and a fresh charge of caustic solution is prepared before the chemical closet is placed in operation again. Operated with intelligence and care the chemical closet is odorless, inoffensive and effective as a means of disposing of human wastes.

Sewage; its genesis and composition. — In the water-carriage (or sewerage) system, which has been so generally adopted, the vehicle of infection is *sewage*. This substance is of special and fundamental importance in sanitary science, first, because it is a vehicle of infection, and second, because of its ubiquity and abundance in modern life. In brief, sewage is made up of all the original vehicles of disease — the washings from the skin, and the discharges from the alimentary, pulmonary, and the genito-urinary tracts.

Sewage treatment may render the liquid wastes from the body innocuous if the methods employed are adequate, but before proceeding to the consideration of this problem, one of the most pressing and one of the most difficult of the sanitary arts, we must inquire somewhat more closely concerning the nature of sewage, its origin, and its fate.

The word "sewage" * signifies "drainage" and may be defined as the contents of drains; but it must be distinctly understood that the drains in this case shall be house drains which contain domestic drainage. The underdrains of a wet piece of uninhabited land, for

* In common parlance the terms "sewage" and "sewerage" are often confounded. It is usual, however, to reserve the latter for the *system of sewers*, and to use always the word "sewage" for the *liquid contents of sewers*.

example, contain drainage but no sewage, since sewage is associated exclusively with the drainage of houses, or at least with the wastes of animal life. Where the sewerage system removes not only the liquid wastes from the home, but likewise the street drainage, sewage is composed of the washings of sinks, the emptyings of water closets, the discharges from laundries, bathtubs, bake-shops, stables, milk plants, factories, and similar places, together with the rain water from roofs and the washings of streets. It may also contain the refuse from slaughterhouses, pus and other substances from hospitals, the washings of markets — and in fact, almost anything capable of carriage by water, and small enough to find entrance into sewers. Nevertheless, ordinary American sewage, on account of its vast dilution, is much less objectionable to look at than is commonly supposed and it often merely suggests in appearance dish-water or a dilute milky liquid with some dirt in suspension. The sewage of European towns is usually much more concentrated than that of American cities, and is therefore darker in color, less watery or milky, and more objectionable in appearance.

The average composition of fresh sewage of certain American cities for 1933 is given below. The analyses indicate that American

TABLE 8

AVERAGE COMPOSITION OF CERTAIN AMERICAN SEWAGES, 1933 *
(Results in parts per million)

INGREDIENT	FITCHBURG	WORCESTER	AKRON	FLINT	GRAND RAPIDS
Nitrogen as free ammonia	17.7	24.1	10.5	12.0	
Organic nitrogen — total	6.9	14.8	21.5		
Oxygen consumed — total	47.4	81.0	160		
Chlorine as chlorides	26.3	97.3	646.	89.	
Residue on evaporation					
Total	332.	840.	1669.	905.	1094.
Dissolved	222	520	1480.	679.	914.
Total iron in terms of Fe	1.80	31.0			
Settleable solids					
cc. per liter after 2 hours				5.1	5.4
Suspended solids	110.	320.	189.	226.	180.
Biochemical oxygen demand					
after 5 days at 20° C.			155.	279.	196.
pH			7.2	7.7	7.3

* From annual reports of the Massachusetts State Health Department and the sewage treatment plants of Akron, Flint, and Grand Rapids for 1933.

sewages vary extensively in composition. The significant factors that influence the composition of sewage include the per capita water consumption in the community, the extent to which the sewerage system is on the combined plan and the nature of the local industries. The location of certain iron and steel mills in Worcester is, for example, reflected in the high iron content of Worcester sewage as compared with that of Fitchburg. Similarly the unusual chloride content of Akron sewage is partly responsible for the high values obtained for total and dissolved solids on evaporation. The data for Fitchburg reflect more closely the composition of a domestic American sewage free of industrial wastes than those given for the other cities listed in the table on page 81.

The dangerous elements and properties of sewage. — That sewage is potentially and actually dangerous has been demonstrated on numerous occasions. Its danger, however, consists chiefly in the disease-producing organisms which may be present. There is reason to believe that if sewage is freed of such organisms small amounts of it could be swallowed without serious harm. The experience in drought affected areas in the United States, where public water supplies have at times become heavily polluted, indicates that in spite of heavy chlorination and the apparent elimination of all disease-producing organisms, minor intestinal disturbances may still be produced by the use of such drinking water supplies. Since sewage contains or may contain the various discharges of human beings and other animals, and since these discharges are vehicles of certain infections, sewage must always be regarded as dangerous. Contact with it should be avoided, and open wounds as well as all food utensils should be thoroughly protected against contamination with it. Although sewage is putrescible and in the active stages of decomposition may give off objectionable odors which may cause temporary distress such as nausea, loss of appetite, and general malaise, it is important to remember that communicable diseases do not arise in this way, and that the evil effects produced are temporary and quickly eliminated. Sewer gases at times may be toxic and even fatal, but it is erroneous to conclude that they are responsible for cases of communicable disease. Such cases arise through direct or indirect contact with other similar cases of disease and their excretions or secretions, and not through the inhalation of gases given off from decomposing sewage.

Importance of the sanitary disposal of sewage. — Inasmuch as sewage may at any time contain any or all of the discharges of the animal body, and furthermore, as these may contain actively infectious materials, the safe and proper disposal of sewage is one of the first necessities of sanitary science and the public health. Among primitive and uncivilized peoples no special pains are taken for the disposal of sewage or the excreta of animals, but in civilized societies various and costly devices are employed to this end. The most primitive method is that in which the wastes of life are simply deposited or thrown out upon the surface of the earth in the neighborhood of human habitations, and when the latter are widely separated little or no harm may result from this practice. When, for example, in country districts or elsewhere, the untidy housewife disposes of dish-water by simplying throwing it from a window, no particular harm may result if the quantity thus disposed of is not too great. We shall shortly see that in this case, and in the similar cases in which manure is applied to land in large quantities and in successive years, the organic wastes present are speedily mineralized or converted into inorganic matters, through the agency of bacteria residing in the soil.

Disposal of sewage in rivers. — Whenever a city or town introduces a system of sewers, it is easy and natural in many cases to dispose of the sewage by simply letting it run from the principal sewer or sewers into a neighboring brook or river or other stream. It is easy, because the natural drainage is in the direction of the river, which is often little more than the principal natural drain of the neighborhood. It is natural, because the river being, as stated, the ordinary drain of the neighborhood, carries off not only the water which falls upon its watershed but also anything that will float upón or mingle with the water; and in most cases even before it is proposed to introduce sewers, the stream has long been used as an easy means of ridding the neighborhood of rubbish or wastes of various descriptions. It cannot be denied that, in case the amount of sewage to be got rid of is relatively small, and provided the stream is nowhere below used as a source of water supply, this practice may not necessarily be objectionable; but even in such cases it is generally unwise, because under slightly different conditions, such as growth of the population upon the watershed, or unexpected drought, the presence of a relatively large amount of sewage may produce a nuisance and prejudice the public health,

finally transforming the stream from something capable of giving pleasure into an open sewer shunned by all mankind.

How, then, has it happened that so many important cities and towns all over the world freely dispose of their sewage by simply turning it into the nearest watercourse? The answer is easy. It is simply because until very lately, engineers, chemists, and sanitary experts alike, held as true, a theory of the purification of watercourses which is now known to be false, or, at best, only a half truth. This was the famous theory of the "self-purification of streams," to a brief consideration of which we may now turn.

Theory of the self-purification of streams. — This theory was based upon the obvious fact that although a very large amount of sewage might be suddenly poured into a stream at a given point so that at that point the pollution was conspicuous and self-evident, it was only necessary to follow the stream for a short distance to perceive that the water had distinctly improved in appearance. This result of mere inspection was strongly confirmed by the chemistry of the time, which proved by actual analysis that the organic matter in the water and the results of decomposition were decidedly less at the lower than the upper point. Naturally, only one conclusion could be drawn from the premises. The stream had somehow purified itself while flowing, and the corollary was deduced that "running water purifies itself."

The importance and far-reaching effects of this conclusion can hardly be overestimated. Relying upon it, numerous cities and towns all over the world introduced water supplies derived from sewage-polluted streams, and infinite damage was done to the public health. The theory has now been greatly modified. There is indeed a considerable purification effected by streams, but it is mostly purification by dilution and the resulting oxidation of the organic matter. The disposal of sewage in rivers is always to be deprecated unless the volume of sewage discharged is very small in proportion to the dry weather flow of the stream in question. It is not to be tolerated if the river below is used without purification as a source of water supply; and it is often not desirable even with such purification.

Sewage disposal in lakes. — Some cities are so situated that it is convenient and natural for them to drain into bodies of fresh water, either lakes or ponds, in which there is little or no current such as always exists in a river. In these cases, the success of the

practice, so far as the mere disposal of sewage goes, depends chiefly upon the proportion maintained between the volume of sewage and the volume of the water into which it is discharged, and which is effective in diluting the sewage. This will be seen most clearly by simply considering the extremes, in which cases for example, a large city empties its sewage into a small pond; or, on the other hand, a small town pours its sewage into a large lake. In the former case the results would be disastrous, the pond being very soon converted into a sewage pool. In the latter, no perceptible effect would be produced especially if the formation of sludge banks is carefully avoided. Obviously, there must be a large class of cases comprising cities and towns of moderate size located upon relatively large bodies of quiet water, which may drain with safety into lakes or ponds; but it is equally clear that there is also another class of cases, comprising for the most part large cities situated upon relatively small bodies of quiet water, which cannot drain into these without seriously prejudicing their purity and possibly producing a nuisance and menace to health.

The case is complicated seriously if either a city or a town draining into a lake or pond undertakes to derive its water supply from the same lake, or if any other city or town makes such use of the water. Furthermore some damage may result if such sewage-polluted waters are used for bathing, fishing, boating, or other recreational activities. There are, as a matter of fact, many cities and towns in the United States that do dispose of their sewage by emptying it into lakes or ponds, but in such cases adequate purification plants have been constructed with the passage of time. Examples of cities and towns bordering the Great Lakes which treat their sewage before discharge are Chicago, Milwaukee, Cleveland, and Toronto. Chicago, as a matter of fact, not only treats a large proportion of its daily sewage flow, but in order to protect its drinking water supply more effectively has now actually diverted all of its raw and treated sewage away from Lake Michigan.

Disposal in harbors, estuaries, and the sea. — Another class of cities and towns, and this includes some of the largest in the world, are so situated that their natural drainage is either directly into the sea or into some tidal harbor or estuary. In these cases it is easy and natural to dispose of sewage by simply pouring it into the sea, harbor, or estuary at some convenient point or points;

and here, also, as in the preceding case, if the city or town is not too large in proportion to the volume of water at its doors, no harm comes from such disposal. There is in this case the obvious advantage that such bodies of water are never used as sources of water supply, so that one serious element or difficulty which exists in the case of lakes and other bodies of fresh water may here be neglected. As a matter of fact, numerous cities and towns on our own coasts pour their sewage into salt or brackish waters, often with entire success and with the absence of all complaint. It is only in some cases that this system of disposal causes trouble, and in these instances the cities are invariably situated not directly on the sea itself, but upon some narrow arm of the sea or some tidal river which virtually limits the size of the body of water into which the sewage is poured. Such a case is that of London, which is situated not upon the sea, but upon a tidal river, and even in the case of London the sources of complaint have been based more upon the alleged obstruction to navigation caused by deposits in the shallow river than upon sanitary grounds.

In the United States the objections to this method of sewage disposal have been based on the fact that bathing beaches have been polluted and bathing rendered unsafe; that shellfish areas have become infected; that serious shoaling has occurred which interferes with the passage of great vessels; that unsightly areas have been created that have interfered with the use of the tidal stream or estuary for purposes of recreation; and that as a result real estate values have been lowered. The nuisance created in New York harbor through the daily discharge of a veritable river of sewage has finally stimulated the local authorities to provide for one of the largest sewage treatment plants in the world. This is to be located on Ward Island and is to purify approximately 180,000,000 gallons of sewage daily. While the situation has not as yet become acute in Boston because Boston's sewage is discharged into the ocean itself, there is little doubt that it has already affected the quality of the water at several popular bathing beaches. While sewage purification by dilution is an admirable process and exceedingly inexpensive, and while we must rely on it to some extent under all circumstances, it is true that in most cases it must be preceded by adequate scientific treatment if a nuisance and menace to the public health are to be avoided.

Principles involved in the disposal of sewage in rivers, lakes, estuaries, and the sea. — In all these cases the fundamental principle of purification, and the basis of successful disposal, is simple dilution by a relatively large volume of purer water. Other factors may or may not cooperate, as, for example, the case of a swiftly flowing river. The mere fact of removal sometimes constitutes an important contribution to successful sewage disposal, the sewage being speedily carried away to a point where its existence is of little consequence. But this is not all. Dilution is the fundamental phenomenon and lies at the bottom of much of the purification which undoubtedly takes place in all these cases. Mere removal does not in itself contribute to purification, while dilution always does.

The phenomenon of stream purification. — Every sewage or sewage effluent must eventually be disposed of by dilution. Where modern methods of sewage treatment are employed, the effluent is invariably discharged into a stream, lake, or tidal estuary directly. Where intermittent sand filtration is employed and the effluent is allowed to become part of the ground water supply, it will find its way eventually into a stream in this way. Frequently, however, raw sewage or partially purified sewage is discharged into a stream directly and whether or not a nuisance is created depends on a great many factors. If the amount of pollution is small and the amount of dilution large, a nuisance will probably not occur. In such a case, the stream will purify itself rapidly. If, however, the amount of pollution is too great for the assimilative powers of the stream, a nuisance will be created. The factors causing the deterioration of a stream are more potent under such circumstances than the counter forces working for its purification.

There are two aspects of stream purification which must be clearly differentiated. One is bacterial purification, and the other, the chemical or biochemical oxidation of the organic matter. The former is favored by quiescence; the latter by rapid dispersal of the sewage and adequate dilution. Each of these will be considered separately.

Bacterial purification of streams. — While dilution brings about an immediate reduction in the total number of bacteria per cubic centimeter, the bacteria do not die out. They are simply carried by the diluting water to a point far removed from the initial source of pollution. In this way disease germs may be carried great dis-

tances, so that water supplies may become readily infected. However, if the water receiving the pollution is quiescent, a series of forces aiming at bacterial purification is initiated almost immediately, and unless additional pollution is introduced, bacterial purification will take place eventually.

The factors that bring about this purification are as follows: Through sedimentation, or the action of gravity, bacteria and the particles of suspended matter to which they are attached will settle out, so that the bacterial content of the supernatant waters tends to diminish and thus to become purified. Sedimentation takes place more effectively and more rapidly in quiescent waters than in swiftly moving streams. The action of sunlight is also of significance in the reduction of the bacterial content of the water. Through the ultraviolet rays of the sun, those bacteria that are either at or near the surface and which are not embedded in particles of suspended matter may be destroyed. Another powerful factor in the bacterial reduction of polluted water is the destructive effect of predatory protozoa and other organisms that feed on bacteria. In addition, there is a variety of other unfavorable influences such as an unfavorable food supply, an incompatible temperature, injurious osmotic relations, unfavorable oxygen conditions, and time — all of which inexorably take their bacterial toll and bring about bacterial purification.

Biochemical stream purification. — A second aspect of stream purification and one that is highly complex, is the biochemical transformation of the organic matter discharged with sewage into a stream. Purification takes place only after the complex phenomena of the nitrogen cycle have been completed. The end result is the oxidation or mineralization of the organic matter. This is initiated by certain groups of bacteria and carried to completion by others, but in the complex series of events which takes place, many other organisms, microscopic and macroscopic, play their part and occupy an important rôle. In order that complete mineralization may occur eventually, oxygen must be present, and it is therefore to a consideration of the physical factor of aëration, as well as to others, that we must first turn.

The aëration of streams goes on constantly. Any factor which tends to break up the surface of a stream favors its aëration. Wind action is especially favorable. So is dilution with water rich in oxygen. A swiftly moving stream is therefore more likely to con-

tain an abundance of oxygen than one that is slow moving or stagnant. Since water can hold more oxygen in solution when it is cold than when it is warm, temperature plays an important part in the aëration of streams. Low temperatures also inhibit biological activity so that organic matter is not decomposed rapidly under such conditions. At the same time, however, the oxygen supply of the stream will not be used up as rapidly, so that a nuisance is less likely to occur. That is why sewage-polluted streams become foul in the summer time and not in the winter.

Certain other influences likewise favor the aëration of streams or tidal estuaries. The constant breaking up of the surface of a stream by the passage of boats favors its aëration. The action of tides and of stream currents as mentioned earlier, results, or may result in greater dilution with oxygen containing water, and must therefore be considered a factor in aëration. Likewise, the depth of water in a stream is important, for deeper waters have greater volume and therefore more available oxygen. Finally, there are various organisms, the green algae for example, which aid in the aëration of streams. These organisms take up the carbon dioxide in the water which they use in building up their food supply, and liberate oxygen. The oxygen dissolves in the water and hence aids in its aëration. Since these chlorophyll-containing organisms require sunlight, any turbidity in the stream which cuts out the sun's rays interferes with their development. In addition, sunlight exerts a bleaching effect on the color in water and this is also desirable.

Still another physical factor that plays a part in stream purification or stream deterioration is gravity or sedimentation. When large quantities of sewage are discharged into a stream, and the sewage has not been deprived of its settleable solids, the solids settle out in the vicinity of the sewer outfall and form what is known technically as sludge banks. If the velocity of flow in the stream is high, the tendency to produce sludge banks will be diminished. On the other hand, if the stream is a slow moving one, or if the sewage has been discharged into a slip or cove, the formation of sludge banks will be fostered. The formation of sludge banks is undesirable because they represent large accumulations of organic matter, which rob the supernatant waters of their dissolved oxygen and create highly objectionable conditions in the stream.

Besides the physical forces that are at work in the process of stream purification, there are chemical and biological factors as well. All three phenomena are interdependent and mutually related to an extraordinary degree. Having discussed the part which the physical forces play, we may now turn our attention to the chemical and biological factors.

The chemical forces that are at work in stream purification are oxidation, reduction, and coagulation. Oxidation results in a transformation of some of the organic matter — dissolved and suspended — to relatively stable substances or to mineral substances which are stable. Besides, such mineral substances as iron and magnesium become oxidized and settle out. Through the process of reduction, some of the mineral matter is put into solution, and the organic matter is hydrolyzed and split and transformed into liquids, gases, and simpler substances more readily available now for the final process of mineralization. Finally, through the action of trade wastes, or through the activity of biological agencies, certain colloidal substances and substances in solution may be coagulated and removed by sedimentation.

Of greatest importance, however, are the biological agencies in stream purification, and of all that are involved probably none is as important as the bacteria. Sewage is alive with bacteria — harmful and otherwise. Every cubic centimeter — about a thimbleful — contains from 1,000,000 to 5,000,000 or more of these microscopic organisms. They attack the organic matter, decompose it, rob the stream of its dissolved oxygen, and keep up their ceaseless activities, either until their food supply is exhausted or until they are destroyed. When the conditions become unfavorable for the continued development of one group, another more adapted to growth and survival may take its place and carry the ceaseless cycle of change that goes on in the mineralization of organic matter one step further. But bacteria have their enemies, and where they are abundant, predatory types of protozoa soon develop and prey upon them. These also perform their share in the purification of the stream, but they are soon invaded by their enemies and so the endless cycle continues until the water is purified and conditions become favorable once more for the survival of major forms of fish life. When these conditions have been attained, the stream may be considered relatively pure once more.

A graphic description of the cycle of events that takes place

among the various forms of life found in water during the process of stream purification was given by Professor G. C. Whipple in his report on the purification of the Genessee River in New York State.* "Immediately below the outlet of the Trunk Sewer there was a zone of heavy pollution, within which the numbers of bacteria were very high but the crustacea very low. Below this point of maximum bacterial life, the numbers of bacteria decreased to the lake (Ontario). In the vicinity of the intense bacterial pollution and for a short distance below it, the numbers of protozoa were high, as might be expected from the fact that these organisms consume bacteria as food. At the same time there was a slight increase in the algae, and their numbers were well maintained downstream to the river mouth. These vegetable cells utilize as food the oxidized products of the organic matter from the sewage. In the lower course of the river, for two or three miles back from the lake, the rotifera and crustacea made their appearance. They live upon the algae and bacteria and especially upon the protozoa. Large numbers of crustacea were found in the lake hovering around the mouth of the river waiting for the food that was being carried to them. These crustacea serve as food for fish and that is why fish are attracted to the mouth of the river, and why fishermen congregate along the breakwaters at the river mouth that extend about half a mile into the lake."

The organisms involved in the self-purification of streams consist, therefore, primarily of bacteria, algae, protozoa, rotifera, and crustacea. Worms, fish, mollusks, and the mold fungi like leptomitus and beggiatoa also play a part in this endless phenomenon, but the most fundamental and important changes in the condition of the organic matter in a stream are brought about by the bacteria. The prevalence of any biological form to a predominant degree in a stream that has been polluted with sewage indicates the degree of pollution which exists at that time. Thus the great preponderance of bacteria over other forms of life in a polluted stream, indicates a more or less septic condition. The second stage in which the diatoms, algae, and protozoa are the most numerous, represents a condition that is no longer septic, but may be described as polluted. The third stage, in which the rotifera and crustacea are predominant, represents a condition that is still less

* *Report on the Sewage Disposal System for Rochester, N.Y., in 1913,* by E. A. Fisher, p. 184.

serious than polluted and may be described as contaminated. Beyond this zone where fish life thrives, the water has become clean.

The rôle played by organisms other than bacteria, especially in the sludge deposits or mud in the zone of maximum pollution, has been studied very thoroughly in recent years as part of the stream purification investigations conducted by the U.S. Public Health Service. W. C. Purdy, the limnologist, has been especially active in the identification of these organisms and their activities. One organism in particular claims his admiration. It is a sludge worm called Limnodulus belonging to the group Tubificidae, and what he says about its activities is of sufficient interest to be recorded here.*

"The writer has had unusual opportunity for observing these worms in the field and studying them in the laboratory, and the following items of interest have been noted:

"1. Preferred habitat. — These worms are found in mud that is foul with organic matter, is usually black, pasty, gaseous, and has a vile odor. The highest number I have thus far found in 1 liter of such mud is over 30,000. If the quantity of mud be limited, as in a tank or vessel in the laboratory, the worms will decrease in numbers as the mud is worked over and its organic content thereby reduced. In an experiment by the writer, a small mass of fecal matter of human origin, buried under such partly exhausted mud in a laboratory culture, was discovered within a few hours by the worms. They migrated from various parts of the container and congregated at the spot where the fecal matter was buried.

"2. How they work. — The worm, about 1.5 inches long when contracted, but 3 to 5 inches when extended, burrows and forages beneath the mud surface, but the posterior third or less of its body is elevated above the mud surface and is usually waving back and forth. The worm seems to eat almost continuously. Observations during 21 hours of the 24 showed no perceptible decrease in its foraging activities, as measured by the fecal pellets which are discharged at about 4 minute intervals from the anal end as it waves back and forth. The average length of fecal material discharged each time is about one-fourth inch. On a conservative basis, supposing the worm to work only three-fourths of the time,

* W. C. Purdy, "A Study of the Pollution and Natural Purification of the Illinois River," *Public Health Bulletin No. 198*, 1930, p. 191.

the above rate results in the evacuation of a string of fecal pellets about 68 inches in length in 24 hours for each worm.

"3. Results of work. — The fecal pellets of these worms are decidedly granular, as compared with the pasty condition of the original mud in which the worms were foraging. An incubation test of 24 hours showed an oxygen demand of 2.8 p.p.m. by these pellets, whereas the original mud beneath the surface showed a demand of 6.7 p.p.m. If the mud surface be lightly covered with powdered chalk, this will in turn be entirely hidden in a few hours by the freshly cast fecal pellets. Thus the worms are operating to effect a continuous overturn of the pasty mud and are meantime depositing a new surface layer in the form of minute granular pellets with lowered oxygen demand.

"The extent of surface on these pellets is probably significant. Careful measurement of about 40 average pellets shows a total area of 26.7 square millimeters. The total volume of these same pellets is 1.03 cubic millimeters. The mud was ingested by the worms below the surface, hence it then had, strictly speaking, no surface exposed to the flowing water. It seems obvious that in the form of fecal pellets the very large total surface now exposed to the flowing water must possess a far more effective method of purification than was possible when this same mud lay in a mass an inch or more beneath the mud surface."

Further knowledge concerning the mechanism of stream purification has also been developed by other workers of the U.S. Public Health Service. For example, E. J. Theriault * has presented experimental evidence to show that the purification of streams polluted with organic matter takes place under aërobic conditions in two stages, the first of which terminates in the oxidation of the carbonaceous material present, and the second stage, beginning only after the first has been completed, in which nitrification occurs. In the first stage, carbonic acid, water, ammonia, and humus-like organic matter are produced; and in the second, the humus material and nitrogenous or ammonium compounds are further changed with the final production of nitric acid (nitrates), carbonic acid, and water. A polluted stream which has undergone purification is rich in dissolved oxygen, low in its biochemical oxygen demand, low in its carbon dioxide content, low

* E. J. Theriault, "The Oxygen Demand of Polluted Waters," *Public Health Bulletin No. 173*, 1927.

in free ammonia, albuminoid ammonia, and nitrites, but high in nitrates, low in oxygen consumed, low in bacteria and the other biological forms indicative of pollution, but high in green plants, rotifers, and crustacea, and is further capable of supporting major forms of fish life. The purification of streams represents today one of the major sanitary and economic problems in the United States. In England, it is said, "there are no rivers long enough to purify themselves." While that is not true of the United States, it serves to emphasize the important fact that streams should be protected against pollution, and that sewage should be treated before it is discharged.

Purification of sewage by the living earth. — Reference has already been made above to the primitive method of sewage disposal in which the wastes of life are got rid of by simply throwing them upon the earth. In this case, and in the similar case in which manure is applied to land in large quantities and for many successive years, the organic wastes present are speedily mineralized or converted into inorganic matters by the agency of microorganisms (bacteria) which reside in the surface layers of the earth in astonishing numbers.

If now we consider what may take place when the organic wastes of life are thrown upon this porous, living earth, we may perhaps understand the remarkable process of purification which takes place. When, for example, the farmer periodically dresses his fields with manure consisting largely of the wastes of animal life, we need not be surprised if, after a time, these wastes seem to have disappeared, while the soil upon which they were placed has grown correspondingly soft and rich. Precisely as, under similar circumstances, the earthworms which are present appear to flourish and multiply under the favorable conditions provided for them by the farmer, so, we have reason to believe, the infinitely smaller microorganisms — which, like the earthworms, reside in the upper layers of the earth — feed, flourish, and multiply upon the food thus provided for them; and exactly as the earthworms work over the materials upon which they feed, reducing them in chemical complexity, and turning organic into inorganic matters, so the myriads of microörganisms which surround them on every hand do their appointed work, and mineralize the organic wastes upon which they too feed.

Thus it is easy to understand how even repeated applications of

large amounts of organic matters, such as stable manure, may be successfully made to a given area of land; or how it happens that the untidy housewife may, with comparative impunity and for a long period, habitually throw from the window upon a limited piece of earth the organic wastes of the kitchen; or, finally, the fact that some of the largest cities in the world, such as Berlin, successfully dispose of their sewage by simply pouring it upon the land. This method of sewage disposal, which is successfully in operation under either natural or artificial conditions all over the world, is at the same time, one of the most primitive, one of the most practical, and one of the most perfect systems hitherto employed by man. This process scientifically controlled has come to be known by the altogether inadequate term "intermittent filtration," and as we shall see, intermittent filtration lies at the basis of all sewage disposal by irrigation and of all successful sewage farming. The process, consisting as it does in a change of organic into inorganic matter, early attracted the attention of chemists, and inasmuch as the purification, chemically speaking, consists largely in oxidation of nitrogenous bodies with conversion of the latter into nitrates, the essential phenomenon is often described as "nitrification."

English experiments on intermittent filtration. — At first it was supposed that nitrification was due to the direct action of the oxygen of the air upon complex nitrogenous bodies, but it was soon perceived that something more must be at work. It was evident, for instance, that stable manure exposed to an abundance of oxygen in the air remained unaffected, while if it were brought into contact with the soil in the ordinary process of agriculture, it speedily disappeared, giving rise to nitrates in abundance. Laboratory experiments showed further that the nitrification could readily be set up by introducing earth into mixtures which it was desired to nitrify, so that it seemed perfectly clear that somehow the earth possessed a specific, nitrifying power.

The first experiments on the disposal of sewage upon land or earth were laboratory experiments made by the Rivers Pollution Commissioners of Great Britain appointed in 1868, in connection with their investigations of the pollution of rivers. In these experiments, glass tubes, sixteen feet long and two inches in diameter, and glass cylinders, six feet long, and either ten and one-fourth or twelve inches in diameter, were filled with various kinds of soil.

Each then received at the top (or in some cases at the bottom) known amounts of sewage which were discharged as effluent at the other end, and in the case of downward intermittent filtration were found to have been remarkably purified. The first significant report of these investigations may be found in the "First Report of the Rivers Pollution Commission," published in 1870 (*Mersey and Ribble Basins*, v. I, pp. 60 70). The facts developed by these experiments remained, however, largely unexplained until a few years later when the investigations of other observers drew attention to the probable cooperation of microorganisms in the processes of nitrification. Moreover, the Commission's experiments were conducted on a laboratory scale, and were limited in number as well as in time.

The problem attacked in Massachusetts. — It remained for the State Board of Health of Massachusetts to take up the problem where the Commission had left it, and to make for the first time extensive and elaborate experiments upon a large scale upon the purification of sewage by land treatment or "intermittent filtration." Inasmuch as these investigations have now become classical, they merit the detailed consideration which they receive below.

The state of Massachusetts, especially in its eastern portion, had become by 1880, so thickly settled that the disposal of the sewage of the numerous cities and towns composing the metropolitan district of Boston, was becoming a serious problem. Accordingly, in 1881, a Commission was appointed to consider and report upon the drainage of the Mystic and Charles River valleys. The report of these commissioners recommended a metropolitan district system which should preserve as far as practicable by general sewerage the purity of the water supplies of the cities included in this district. In 1884 the Massachusetts Drainage Commission was appointed, and in 1886 their report was published, giving a large amount of valuable information regarding sewage disposal theories and practices in England and on the Continent. Perhaps the most important work which they accomplished, however, was their earnest recommendation that the Commonwealth of Massachusetts should appoint a Commission or designate Guardians to conserve the purity of the inland waters of the state, such body to be provided with advisory rather than mandatory powers.

"Let these guardians of inland waters be charged to acquaint themselves with the actual condition of all waters within the state as respects their pollution or purity, and to inform themselves particularly as to the

relation which that condition bears to the health and well-being of any part of the people of the commonwealth. Let them do away, as far as possible, with all remediable pollution, and use every means in their power to prevent further vitiation. Let them make it their business to advise and assist cities or towns desiring a supply of water or a system of sewerage. They shall put themselves at the disposal of manufacturers and others using rivers, streams, or ponds, or in any way misusing them, to suggest the best means of minimizing the amount of dirt in their effluent, and to experiment upon methods of reducing or avoiding pollution. They shall warn the persistent violator of all reasonable regulation in the management of water, of the consequences of his acts. In a word, it shall be their especial function to guard the public interest and the public health in its relation with water, whether pure or defiled, with the ultimate hope, which must never be abandoned, that sooner or later ways may be found to redeem and preserve all the waters of the State. We propose to clothe the board with no other power than the power to examine, advise, and report, except in cases of violation of the statutes. Such cases, if persisted in after the notice, are to be referred to the attorney general for action. Other than this, its decisions must look for their sanction to their own intrinsic sense and soundness. Its last protest against wilful and obstinate defilement will be to the General Court. To that tribunal it shall report all the facts, leaving to its supreme discretion the final disposition of such offenders."*

Reorganization of the State Board of Health of Massachusetts. — The legislature of 1886 promptly adopted the recommendation of the Drainage Commission, and turned to the State Board of Health as the proper body to undertake the new and important functions which it was proposed to create. The Board was reconstituted and reorganized, and endowed not only with the usual powers and duties of a State Board of Health, but with entirely new and peculiar functions in regard to the water supplies and sewerage of the towns and cities of the commonwealth. The Board was to become the expert sanitary adviser of the towns, and *a fortiori* of the legislature, in these particulars; and it was to be liberally supported. As a special recognition of the new functions, Mr. Hiram F. Mills, of Lawrence, a distinguished hydraulic engineer, was made a member of the reorganized Board, and immediately took charge of the experiments upon intermittent filtration. The statute which provided the new functions for the Board was approved on June 9, 1886, and the Board immediately proceeded to carry out the provisions of the act, and its first report was dated January, 1887.

* *Massachusetts Drainage Commission Report*, Boston, 1886, p. lxi.

The Massachusetts experiments at Lawrence. — The first problem attacked at the Lawrence Experiment Station was that of the best method for the disposal of sewage upon land. English and German experience had made it probable that much might be done in this direction in America; but the knowledge available was very limited and of little or no practical value to American engineers, because the climates, soils, sewages, and civil and economic conditions of America are so different from those of Europe. Accordingly, in November, 1887, a series of careful experiments was begun, to test the purifying capacity of various soils and sands occurring in Massachusetts.

For this purpose a number of large wooden tubs or tanks built of cypress were filled with different soils, ranging from muck and garden loam on the one hand, through fine sand and coarse sand to mixed gravel stones, coarser materials, and pebbles on the other. The soil or sand to be tested was in each case supported by a stratum of stones and gravel, and underdrained through an effluent pipe which emptied into a large measuring basin. The sewage was also measured as it flowed on at the top, and the whole experiment was under control in every respect. Each tank, or "filter," was sixteen feet in diameter, or one two-hundredth of an acre in area, and the filtering material in each case was five feet in depth. The sewage, drawn from one of the main sewers of the city of Lawrence, was ordinary domestic city sewage, free from manufacturing wastes. No experiments of this kind had ever before been undertaken on such a scale or with so much care. For the first time in the history of science, engineers, chemists, and biologists worked together under capable direction for the promotion of the public health.

The results crowned the endeavor. As soon as a few days had passed, and the filters had become established, the effluent began to grow bright and clear. Chemical analyses showed that the output was now purified sewage, comparatively free from odor, and poor in organic matters. Bacterial analyses showed that while sewage was swarming with the germs of putrefaction and decay, the effluent contained only a few bacteria. Further studies revealed the fact that the foulness of the sewage was not held back as by a strainer; but rather that as wood by a slow fire is turned to ashes, the organic matters here were slowly being reduced to mineral substances. No disagreeable odor developed, and the filters showed

no signs of clogging. Thus the very name "filter" became a misnomer.

Anatomy and physiology of intermittent filters. — Meanwhile the data of the experiments were accumulating. Winter came on, and still the "filters" did their work. Already it was proved that land-disposal of sewage was possible for America. But, curiously enough, those soils — such as muck and garden loam — which many had predicted would be the most useful, proved to be the least effective. They were too close in texture, too fine, too impervious; while sand (such as ordinary mortar sand) or even fine gravel proved to be the most effective. The reason for this is that the whole process is a vital one. The soils are not mere strainers, for at the very outset they fail to work. They are rather like the living sponge — an animal whose body is everywhere channeled with fine passages lined with living cells. The fine passages in the body of the filters are the spaces between the sand grains; the living cells are the microorganisms which, after a few days, come to dwell upon the sand grains and line the passages. And very much as the living cells of a sponge detain and destroy the organic particles passing by them, the bacteria resident upon the sand grains detain and work over the organic matters of the sewage poured upon the filter. Again, exactly as the living organisms of which a sponge is essentially composed require oxygen to support their respiration, so those inhabiting a filter must have abundant air. This means that the sewage, which is usually destitute of oxygen, must not be applied continuously, but *intermittently*, so that air may follow it down through the filter and keep from suffocation the purifying microorganisms. And this also explains why intermittent downward filtration, under the right conditions, is always successful, while continuous filtration, or upward intermittent filtration of sewage inevitably fails.

With the main principles once established, it remained only to learn the details of their application. Sand proved better than loam, because it allowed better ventilation. Fine sand proved better than coarse sand, because it seems to be the happy mean, giving full exposure to the air by distributing the sewage in thin films over a vast number of surfaces, but yet allowing sufficient ventilation.

The process is exceedingly efficient, transforming city sewage into an effluent resembling drinking water. Its applicability,

however, depends on the availability of the necessary land area and the type of sand — the glacial drift variety — found to be effective. Subsequent methods have replaced intermittent sand filtration as a common means of sewage treatment because of the saving in land area and because of the higher rates of treatment which they afforded. None, however, has yet been able to give the high degree of purification accomplished by the intermittent sand filter.

Theoretical aspects of intermittent filtration. — The transformation of organic matter in the intermittent sand filter can be best explained on the basis that combined biological, physical, and chemical forces are at work effecting the purification. When a sand filter is first placed in operation, it acts simply as a strainer. Soon, however, the sand grains become coated with an organic slime, made up of the suspended solids in the applied sewage and the bacteria and other microörganisms it contains. When fresh sewage is now applied, some of the solids and their adhering bacteria are removed by straining and sedimentation. The bulk of the finely divided matter, including the bacteria, commonly spoken of as colloidal matter, is removed by a surface phenomenon exhibited by the slime layer around the sand grains technically known as adsorption. During the prolonged period of rest between doses of sewage, the bacteria which are resident in the slimy coat surrounding each sand grain, oxidize the organic matter removed, through the successive stages of ammonia and nitrites to mineral substances called nitrates. These in turn are soluble in water and can be removed in part from the filter with each application of sewage. The formation of nitrates is the result of biochemical action. There is a certain small amount of direct chemical oxidation of the organic matter, but it is rather insignificant in quantity. It is proper, therefore, to say that "upon the biological theory, an intermittent filter is no longer to be regarded as a mechanical strainer, nor is it merely a chemical furnace; it resembles a living organism."

Sewage farms. Objections. — The disposal of sewage by means of irrigation naturally involves the establishment of sewage farms, that is, a special kind of farming in which a liquid fertilizer such as sewage is supplied in abundance and sometimes in superabundance. The practical value of sewage as a fertilizer however falls far below its theoretical value, owing chiefly to its enormous dilution. Any combination of farming with sewage disposal is, if

closely examined, of doubtful economic wisdom, at least at present, in America. It does not by any means follow that because sewage contains valuable fertilizing elements it is therefore wise for every city and town having sewage to dispose of to undertake sewage farming. There can be no doubt that a greater area of land is required for successful sewage disposal by sewage farms than by mere intermittent filtration, and it is of very dubious wisdom, at least in the United States where land in the neighborhood of cities is dear, where municipal servants are likely to be highly paid, and where, also, agricultural produce is relatively cheap, to undertake sewage farming either for economic or aesthetic reasons.

There is also the sanitary objection, the force of which must to some extent be admitted, that vegetables and small fruits grown upon sewage fields and presumably watered with sewage are liable to become contaminated with infectious materials. We must probably allow that lettuce, cabbages, radishes, strawberries, and similar vegetables or fruits, if so watered or flooded, may possibly become thus contaminated, and if the foods are consumed raw, as they often are, may represent a significant, potential menace to the public health. Certainly, the experience of the Orient, where night soil or human excrement is used as fertilizer, would tend to support this point of view. In America, sewage farming has had only a very limited application. Wherever the principles involved were utilized, preference was always given to the intermittent sand filter. For reasons already enumerated, however, the intermittent sand filter, in the United States, has given way to the trickling filter and the activated sludge process.

Reasons why sewage must be treated. — The relationship of infected water to disease has been established so definitely that little difficulty is experienced today in convincing municipal authorities of the wisdom of filtering and chlorinating public water supplies, and of the importance of protecting drinking water against pollution at its source. The case for sewage treatment is not so obvious, and an uninformed public is apt to regard the expenditures for sewage treatment purposes as desirable but not essential. However, even here, sentiment is changing slowly but surely. The closing of public bathing beaches by health authorities because of the potential danger from pollution, the spread of disease through infected shellfish, the elimination of major fish life from waters erstwhile bountifully supplied, the marked depreciation

of property values near sites of gross pollution, and the noisome conditions arising from decomposing sewage, from unsightly floating materials, from oil wastes and other sources of pollution, have been so impressed on the public mind lately as not to be without definite effect. It is therefore of some value to list here the reasons why sewage should be treated before it is discharged into a nearby stream, lake, or tidal estuary.

1. The preservation of the public health.
   a. By preventing the pollution of waters used as sources of drinking water — usually by others.
   b. By preventing the pollution and probable infection of oysters, clams, and other shellfish.
   c. By preventing the pollution of waters used for bathing purposes.
   d. By preventing people and insects from coming in contact with human excrement in sewage, or with objects so polluted.
2. The promotion of aesthetic ends.
   a. By preventing the formation of conditions resulting in the liberation of foul odors and gases.
   b. By preventing the marked discoloration of streams, resulting from the discharge of raw sewage.
   c. By preventing the appearance of large amounts of objectionable floating material in streams.
3. The promotion of commercial and economic ends.
   a. By preventing the destruction of major forms of fish life.
   b. By preventing possible injury or damage to livestock.
   c. By preventing deterioration of property values in the vicinity of heavily polluted streams.
   d. By preventing the deterioration of harbors and streams used for navigation by shoaling, through the constant deposition of sewage solids.

In addition, the proper handling of the sewage problem in every community necessitates some attention to the condition of catch basins, especially during the warmer months of the year, in order to prevent the development of obnoxious gases and odors resulting from the decomposition of accumulated organic matter, and the breeding of mosquitoes in the stagnant water. Accordingly, catch basins should be cleaned to prevent the accumulation of organic matter, and during the mosquito breeding season they should be oiled about once in 7 to 10 days to prevent the development of mosquitoes.

Objectives of sewage treatment processes. — Various sewage treatment processes have been developed to diminish or eliminate

the objectionable conditions arising from the careless and unsatisfactory disposal of municipal sewage. In general, the objectives are fourfold:

1. To diminish the amount of solid materials discharged into a stream, in order to lessen the demands on its purifying properties, and to prevent the formation of sludge banks and the appearance of objectionable floating materials.
2. To decompose, through the agency of biological methods, the organic matter in sewage, and to transform it into simpler organic compounds, and into gases and liquids. In this way, the burden of the final purification which takes place in a stream will be greatly diminished. This decomposition of the organic matter is accomplished through anaerobic methods of sewage treatment.
3. To stabilize the organic matter in sewage through the agency of biological methods operating under aerobic conditions, so that the purifying properties of a stream into which the treated sewage is ultimately discharged will be taxed to a minimum.
4. To diminish or destroy the bacteria present in sewage, particularly the pathogenic varieties capable of producing disease.

Methods of sewage treatment.—Having recorded the objectives of sewage treatment processes, it is possible now to examine the methods of sewage treatment by which they are accomplished.

1. The removal of suspended solids.
   A. By screening.
      a. Through coarse screens.
      b. Through fine screens.
   B. By rapid sedimentation for the removal of grit or detritus.
      a. In grit chambers or detritus tanks.
   C. By slow sedimentation without coagulants.
      a. In horizontal flow tanks — plain settling tanks.
      b. In vertical flow tanks — Dortmund tanks.
   D. By slow sedimentation with coagulants.
      a. Chemical precipitation.
2. Anaerobic decomposition of organic matter after sedimentation.
   A. In single story tanks.
      a. Septic tanks.
   B. In two story tanks.
      a. Imhoff or Emscher tanks.
3. Oxidation processes for stabilizing the organic matter.
   A. Broad irrigation or sewage farming.
   B. Intermittent sand filtration.

* Anaerobic decomposition of organic matter takes place to some extent in sedimentation tanks, chemical precipitation tanks, and even in grit chambers, although such decomposition is not one of the objectives of these treatment processes.

C. Contact filtration.
D. Trickling filtration.
E. Activated sludge.

4. For the destruction of pathogenic microbes.
A. Disinfection, usually with chlorine.

5. For final disposal.
A. By dilution.

Sewage treatment plants are always composed of varying combinations of the processes listed above. In Worcester and Fitchburg, for example, the treatment employed is a combination of coarse screens, grit chambers, Imhoff tanks, trickling filters, secondary sedimentation basins, and final disposal by dilution. In many other smaller Massachusetts cities and towns, such as Concord, Framingham, Gardner, Hudson, Marlborough, and Pittsfield, the method of sewage treatment consists of coarse screens, intermittent sand filtration, and final disposal by dilution. In some of the newer and larger sewage treatment works, either in operation or under construction, notably Milwaukee, Indianapolis, Chicago (North Side), and New York (Ward Island), the method of sewage treatment consists of coarse screens, grit chambers, activated sludge, secondary sedimentation basins, and final disposal by dilution. These are illustrations of modern methods of sewage treatment actually in use, which are giving satisfactory results.

Sewage treatment *versus* sewage purification. — There is not the slightest doubt that the art and science of sewage treatment have been developed to such a point that it is possible to transform a municipal sewage into an effluent that compares favorably in quality with many drinking water supplies. Such refined treatment is usually expensive and ordinarily unwarranted. All streams have the property of assimilating organic matter in sewage to some extent without creating a nuisance, and it is both wise and economical to utilize existing facilities in this way. Communities, therefore, are rarely called upon to purify sewage where adequate facilities for dilution and hence for final purification are available. Such communities need only to treat sewage to a point where final disposal in a stream can be accomplished without causing any serious deterioration to the stream. The aim of sanitarians, therefore, is adequate treatment of sewage for local needs, rather than complete purification before discharge.

Sewage treatment in fine screens *versus* Imhoff tanks. — Municipal sewage in America is so dilute that the use of fine screens has been of doubtful value. In comparative studies made at the Brooklyn Sewage Experiment Station, a larger proportion of the suspended solids in sewage was removed by sedimentation in Imhoff tanks than by treatment with fine screens. The Imhoff tank also provides a satisfactory method of treating the resulting sludge, whereas some satisfactory method of disposal for the screenings must always be employed when fine screens are used. But in the treatment of concentrated industrial wastes or the first flush of storm water, a possible field of usefulness does exist for fine screens as a means of removing an adequate proportion of the concentrated suspended solids present in such wastes. Neither fine screens nor Imhoff tanks can be considered final methods of sewage treatment, since the effluent from each contains much colloidal matter which is largely organic in nature and which is highly putrescible.

Coarse screens. — These consist of stationary, parallel bars, placed either vertically or at an angle of 30° to 45° to the sewage flow, and serve the purpose of removing from the sewage coarse and unsightly floating objects. The removal of these objects is essential in order to prevent injury to pumps and other sewage appliances.

Grit chambers. — A grit chamber is a tank-like arrangement with regulatory controls which permit crude sewage to pass through at a velocity of approximately 1.0 foot per second. This velocity of flow is theoretically able to maintain finely divided sewage particles of organic origin in suspension, and at the same time to permit the heavier, inorganic particles, the grit, to settle out. Since this material does not undergo biological decomposition and simply serves to clog sewage appliances or to take up space in tanks or filters, its preliminary removal from sewage is essential. Unfortunately, grit always contains more or less organic matter, so that some attention must be given to its final disposal if a nuisance is to be avoided.

Plain sedimentation. — The removal of suspended solids from sewage by plain sedimentation may be accomplished either in horizontal or vertical flow tanks.. As a general rule, the tanks are operated on a continuous flow basis. Usually, the period of retention is about 2 to 3 hours. The velocity of flow through a

sedimentation tank varies from 0.1 to 0.01 foot per second. About 50 to 70 per cent of the suspended solids are removed by this method of treatment, which yields about 4 to 6 cubic yards of sludge per million gallons of sewage treated. The sludge must be removed at frequent intervals, as often as once or twice a week during the summer months, and less frequently during the winter. The process is excellent for preliminary treatment and is often used in conjunction with sludge digestion in separate tanks. In some instances it has been replaced by the Imhoff tank, which combines the principle of sedimentation with that of sludge digestion.

Chemical precipitation. — This method was developed in England about 70 years ago,* and its purpose was to produce a clearer effluent than that provided by any other method of treatment available at that time, and to yield a sludge which would have economic value because of its possible use as a fertilizer. Unfortunately, the sludge has a high moisture content, about 95 to 97 per cent, and as the removal of the excess water is expensive, the sludge resulting from this process has never been employed extensively as a fertilizer. In New England, Worcester and Providence have employed chemical precipitation for years, but in both instances, this method of treatment has been superseded by others that are more modern and less expensive.

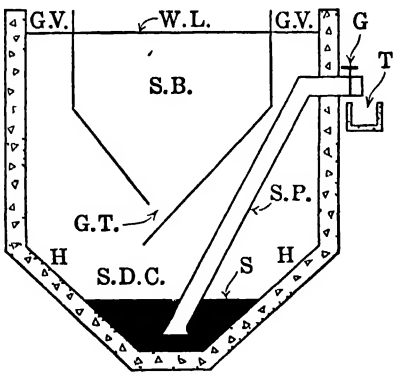
The chemicals employed may be either lime, or lime and ferrous sulphate combined, or lime and aluminum sulphate combined, or lime and ferric chloride. About 60 to 80 per cent of the suspended solids are removed, although at times the per cent removal may be greater or less, and the sludge produced approximates 20 to 25 cubic yards per million gallons of sewage treated. An enormous problem of sludge disposal is created, which must be adequately solved. This method of treatment is not used extensively today, although various attempts have been made recently to revive it.

Single-story septic tanks. — This method of treating municipal sewage was widely employed in the United States prior to the introduction of the Imhoff tank. At present, the latter method has replaced it almost entirely. In some cases, however, septic tanks have been converted into plain sedimentation basins, and the resulting sludge has been treated in separate sludge-digestion tanks. Considerable difficulty has been experienced with odors resulting

* *Second Report, Rivers Pollution Prevention Commission of 1868*, London, 1870.

from the septic tank process, and where septic action has proceeded too far, subsequent aerobic methods of treatment have not worked very satisfactorily. This method cannot be considered a final method of treatment. Its use today for larger installations is not recommended.

Imhoff tanks. — The Imhoff tank is a two-story tank, the upper compartment, S.B., being used as a sedimentation basin, and the lower one as a sludge-digestion chamber. The period of retention of sewage in the settling chamber is about 2 to 3 hours. The solid particles capable of settling pass through the slot S, into the sludge-digestion chamber below. There the sludge undergoes decomposition under anaërobic conditions, with the liberation of gas. If allowed to escape, the gas passes out into the atmosphere through the gas vents, G.V. The gas trap, G.T., prevents the gas from passing up into the sedimentation chamber, thus preventing any interference with the sedimentation process. Sometimes, when the gas is largely methane, it is collected and used either for heating or lighting purposes.



W.L. = Water Line
S B. = Settling Basin
S D.C. = Sludge Digestion Chamber
G V. = Gas Vent
G.T. = Gas Trap
G = Gate-Valve
T = Trough
S P. = Sludge Pipe
H = Hopper-Shaped Bottom
S = Sludge

FIGURE 1. Diagrammatic representation of Imhoff tank

In addition to the gasification of the organic matter which this method of treatment accomplishes, the decomposable material is transformed into liquids and other simpler substances. A black, viscous sludge, full of entrained gas, is finally obtained, which can be drawn off through the sludge pipe, S.P. at T by opening the gate-valve G and allowed to flow on to sludge drying beds with which trough T is connected. The sludge dries quite readily, is

greatly reduced in volume, and is inoffensive. This method of treatment is quite effective and is used extensively in the United States today. Among the modern sewage treatment plants in New England which use Imhoff tanks are those at Fitchburg and Worcester. At the latter plant, the Imhoff tanks are 90 feet long, 61 feet wide, and 31 feet deep. Each tank has two sedimentation basins and two rows of sludge-digestion chambers. The capacity of the sludge-digestion chambers is approximately 2.5 cubic feet per capita served. Trained and intelligent operation is absolutely essential for satisfactory results. In order to hasten sludge digestion in a new Imhoff tank, and to insure the development of the right kinds of microörganisms required for sludge digestion, it is customary to seed new tanks with ripe sludge obtained from another tank that has been in operation for some time. Imhoff tank treatment has proved to be very effective, but it must be regarded only as a preliminary method of treatment and not as a final one.

Contact filtration. — This method of sewage treatment was developed in England, and although it does not yield as satisfactory an effluent as the intermittent sand filter, it makes it possible to treat sewage at the rate of almost 800,000 gallons per acre per day. This method was employed in the United States primarily in New Jersey and Ohio, but in most places it has long been superseded by more modern and more satisfactory processes.

It consists of a water-tight basin, usually about 0.2 to 0.25 acre in area, which is provided with underdrains. Over the underdrains is placed a filtering medium like broken rock which does not disintegrate readily. The depth of the filtering medium may vary from 3 to 4 feet up to 6 feet. After the filter is ripened with use, sewage is applied usually 2 or 3 times every 24 hours. There is a full period, during which the organic matter in the sewage is broken down anaërobically, which is followed by a long, empty period, during which the simplified organic matter is oxidized through the agency of bacteria to more stable substances. Eventually the filter medium must be removed, dried, washed, and replaced before the filter can be placed in operation once more.

Trickling filtration. — This is one of the most common methods of sewage treatment in use in the United States today. It is employed at Worcester, Brockton, and Fitchburg, Mass., at Baltimore, Md., at Schenectady and Rochester, N.Y., at Akron, O., at Flint, Mich., at Aurora and Bloomington, Ill., and at numerous

other places. It is preceded usually by using coarse screens, grit chambers, and Imhoff tanks for the sewage under treatment.

The trickling filter consists of a basin, suitably underdrained, above which are about 10 feet of broken trap rock or other suitable material, having a size which local experimentation has demonstrated to be satisfactory for the sewage under treatment. The effluent from the preliminary treatment processes is applied to the filter through stationary nozzles, usually from special dosing tanks, where a gradually diminishing head makes it possible to apply the sewage in the form of a spray in uniform amounts to every square foot of filter area. Revolving distributors operated mechanically which dose the filter uniformly have also been employed, especially in England.

In time, the filter medium becomes coated with a zoögleal or jelly-like growth, which abounds in bacteria and other microorganisms. These organisms play the important rôle of transforming the organic matter in the sewage to stable end products like nitrates. The effluent after sedimentation is remarkably clear and stable, and shows a bacterial reduction from the content of the raw sewage, equivalent to 90 per cent. The trickling filter treats sewage at the rate of 2,000,000 gallons per acre per day, and under favorable conditions the rate may be increased to 3,000,000 and even 4,000,000 gallons per acre per day. After sedimentation, the trickling filter effluent can usually be discharged into a stream with impunity. It must be regarded as a satisfactory and reasonably cheap method of sewage treatment. One unusual feature of this method of sewage treatment is that the filter cleans itself automatically during the summer months when it unloads some of the suspended matter it has accumulated.

Activated sludge. — Although various efforts to purify sewage by aëration without the use of a filter medium had been made at the Brooklyn and Lawrence Sewage Experiment Stations the applicability of the activated sludge method of sewage treatment on a large scale and in its present form was first demonstrated in England in 1914. Its popularity has been widespread, as its rapid introduction in this country indicates. Among the more important plants in operation or under construction are those at New York, Chicago, Milwaukee, Indianapolis, Woonsocket, R.I., Pasadena, Calif., and Houston, San Marcos, and Sherman in Texas. The effluent from this method of treatment, after sedi-

mentation, is remarkably clear and stable, and shows a bacterial reduction from raw sewage of 90 to 98 per cent. This effluent can invariably be discharged into a stream with impunity. The rate of treatment is about 10,000,000 gallons per acre per day, and the sludge produced is very rich in nitrogen and phosphorous. Accordingly, in spite of its high moisture content, about 98 per cent, it has distinct possibilities for sale as a fertilizer after dewatering. In order that the process may operate successfully, it is important that the sewage should not contain injurious trade wastes in such concentration as to inhibit the development of the bacteria and other essential microorganisms. The process is an aërobic one and yields an effluent which is rich in nitrates.

An activated sludge tank is built of varying dimensions for width and length, but in this country the effective depth is usually about 15 feet. Each tank is provided with means for supplying compressed air to the sewage. In practice, the air is supplied through special diffusers, one of the common types being the filtros plate. Filtros is a compound made of ground quartz sand and a silicious binding material, and baked until it becomes hard. The purpose of the filtros plate is to break up the air into very fine bubbles in order to expose the maximum air surface to the sewage through which it passes. It is essential that the air be free from oil and dust particles.

In order to start a new activated sludge tank, thoroughly aërated activated sludge must be obtained from a plant already in operation, or the necessary activated sludge must be accumulated at the new plant itself. If ripened activated sludge is not available the jelly-like growths occurring on the stones of a trickling filter may be substituted. If the activated sludge must be manufactured raw sewage is allowed to flow into the tank, and air is blown through it until it is stable. The air supply is then shut off, the sludge is allowed to settle, and the supernatant liquid is drawn off and discarded. Fresh sewage is now introduced, and is aërated in contact with the accumulated sludge from the first treatment, until the second batch of sewage becomes stable. The air is shut off once more, the increased volume of sludge allowed to settle, and the supernatant liquid is discarded. This process is repeated until the volume of aërated or activated sludge is equal to 20 per cent of the volume of sludge and sewage combined. A proper proportion of activated sludge can be accumulated more

rapidly by partially stabilizing each dose of sewage instead of carrying the stabilization to completion. The partially stabilized sludge is then oxidized until it is fit for use. The activated sludge tank is then capable of operating on a continuous flow plan, fresh sewage being introduced, and an equivalent amount of aërated sewage and activated sludge being removed. The effluent is now treated in secondary settling tanks for a relatively brief period, and, as the activated sludge settles out very rapidly, the highly purified supernatant liquid is allowed to flow out into a nearby stream or body of water. The sludge may be returned to the activated sludge tank if necessary, or if this is not required, it may be treated for ultimate disposal.

Two methods of treating the excess activated sludge have been developed. One is to digest it in Imhoff tanks or in separate sludge-digestion tanks under anaërobic conditions, and the other is to dewater the activated or digested sludge, and to use it after drying as a source of fertilizer material.

In the trickling filter the jelly-like growths which effect the purification of the sewage occur on the surfaces of the stones. In the activated sludge process, this flocculent, jelly-like mass containing the bacteria and other microorganisms necessary for purification, is moved throughout the mass of the incoming sewage, by means of the compressed air which is blown through it. The colloids in the sewage are coagulated and settle out readily, and the liquid portion of the sewage becomes almost as clear as drinking water.

Another important function of the compressed air is to supply the necessary oxygen for the bacteria to perform their work. In general, about one cubic foot of air is supplied for every gallon of sewage treated, and the period of aëration varies from 5 to 6 hours. Enough filtros plates are provided in the floor of each tank so that the ratio of filtros plate area to the area of the tank is as 1:7 to 1:10.

This method of sewage treatment is unquestionably one of the best yet developed and can properly be considered adequate for final disposal even under exacting conditions. However, the enormous volume of sludge resulting from this method of treatment presents a major disposal problem. It is possible to meet this problem satisfactorily in the manner indicated above, and since the sale of the sludge after suitable dehydration yields some return, the question of ultimate disposal does not present insur-

mountable financial or scientific obstacles. It is very likely, therefore, that the activated sludge method of sewage treatment will be adopted more generally in the future. This method of treatment is extremely technical and will always require trained and capable supervision.

Sewage disposal by dilution. — Regardless of the method of sewage treatment employed, the ultimate disposal of the sewage or sewage effluent must be by dilution. The increasing pollution of rivers, lakes, and tidal estuaries has made the question of stream purification one of the important public problems of today. While a stream can assimilate a certain amount of pollution, the demands that are made upon it should never exceed the limits of its purifying properties.

Stream purification is essentially a relationship between the dissolved oxygen present in the water and the oxygen required to stabilize the organic matter discharged into the stream in the form of sewage. It is important therefore that the dissolved oxygen content of a stream should not be allowed to fall to a point where a nuisance will be created or where fish life will be destroyed. It is estimated that water must contain at least 4.0 parts per million of dissolved oxygen in order to maintain desirable forms of fish life. Furthermore, if the percentage saturation of dissolved oxygen in a stream is not permitted to fall below 50 per cent, it is likely that no nuisance will exist. No dependence can be placed on the rise and fall of tides to dilute sewage-polluted streams sufficiently. Furthermore, sea water contains 20 per cent less dissolved oxygen than fresh water under similar conditions of temperature and pressure, a fact which emphasizes the importance of treating sewage discharged into tidal estuaries. Sea water also exerts a precipitating effect on the colloids in sewage, a condition that favors the formation of sludge banks when sewage is discharged into salt water.

The fate of infectious matter in sewage treatment processes. — From what has already been said, it is apparent that there are numerous unfavorable influences at work aiming at the elimination of pathogenic bacteria which are introduced into lakes, streams, and tidal estuaries with sewage. The inescapable conclusion must be drawn, therefore, that if the sewage pollution is not great in amount, and if the beneficent influence of storage, sunlight, predatory infusoria, lack of proper food, unfavorable temperature

relations, and unfavorable oxygen relations obtain, pathogenic bacteria introduced in water do not survive for extended periods. On the other hand, they tend to die out rather rapidly.

When we come to the disposal of sewage upon land we find the question of the fate of pathogenic bacteria in the sewage somewhat similar. If the sewage to be purified is passed through, and not merely over the earth, the microorganisms which it contains are held back more or less completely, along with other suspended matters by the living earth; and one of the striking phenomena of intermittent filtration is the disappearance of the numerous living bacteria always present in the crude sewage when the effluent is examined. Some of these, no doubt, are mechanically detained in the upper layers of the living earth while others perish from lack of proper food and other unfavorable influences. In the sewage filters at the Lawrence Experiment Station it became evident very early that a high degree of nitrification was always accompanied by a remarkable disappearance of bacteria, and repeated experiments have shown that the effluent from a good sewage filter is incapable of supporting any considerable population of bacteria. There is no doubt, however, that under certain circumstances bacteria applied to the surface of an intermittent filter may live to find their way into the effluent. Although the effluent is relatively free of bacteria and compares favorably in quality with many drinking waters it is always safer practice to disinfect it with liquid chlorine if it is discharged directly into a source of water supply.

If it be asked what becomes of the pathogenic bacteria held back by the sand of the intermittent filter, the answer is that they do not appear ordinarily to multiply, but rather to perish, along with the myriads of putrefactive bacteria which accompany them in the sewage. Similarly, in the case of sewage treatment by chemical precipitation, most of the pathogenic bacteria are carried down by the precipitant and are found in the sludge. However, since the effluents from chemical precipitation works cannot safely be admitted into a body of water used for drinking purposes, it is necessary to disinfect it thoroughly before it is so discharged.

As to the effect produced on the pathogenic bacteria by the natural decomposition of the organic matter in sewage in the septic tank or in the Imhoff tank, there is every reason to believe that here, too, they are removed and destroyed in time in the struggle

for existence with other organisms in the decomposing sludge, which are more fitted to survive under the existing conditions. The liquid portions of the sewage, which remain in the septic or Imhoff tank for periods varying from 2 to 24 hours, cannot be considered safe, since the time is altogether too short for the pathogenic bacteria that may be present to be destroyed. Such effluents, therefore, must always be considered dangerous and should never be discharged into a stream that is used as a source of drinking water without further purification and disinfection. At least the water ought to be purified before it is used for drinking purposes.

In a well-operated trickling filter, especially after the effluent has been treated in secondary settling tanks to remove the settleable solids, the bacterial reduction in the final effluent when compared with crude sewage, may be as high as 90 to 95 per cent. Furthermore, the character of the bacteria has been markedly altered and those that are present are mostly of the nitrifying type. In all probability none of the pathogenic bacteria originally present in the crude sewage are present in the final effluent from a well-operated trickling filter; but if the effluent is to be discharged over oyster beds or into a stream used as a source of drinking water, it would be wiser to disinfect it with liquid chlorine.

What was said of the trickling filter that functions properly is equally true of the activated sludge process when it is functioning satisfactorily. The bacterial reduction in the effluent may be as high as 98 per cent. The character of the bacterial flora here has also been completely altered. While it is highly probable that all pathogenic bacteria have been removed or destroyed, it is unwise to count on absolute bacterial purification, and wherever that is essential, recourse should be had to disinfection with liquid chlorine before the final effluent is discharged. Sanitarians prefer to go on the basis that "It is better to be safe, than sorry."

Conclusion. — The sewage disposal problem represents one of the large and vexing municipal and sanitary problems of the day. The knowledge for its proper solution is available. There are needed only an aroused civic consciousness and the necessary financial support, to bring our streams back to a condition of purity and decency which the maintenance of the public health, the promotion of aesthetics and comfort, and the protection of our economic interests demand.

CHAPTER VIII

REFUSE COLLECTION AND DISPOSAL

The refuse disposal problem. — There are three primary municipal sanitary functions: first, the provision of a safe and adequate water supply; second, the provision of a sewerage system for the removal of the liquid wastes, and a suitable means of treatment before final disposal; and third, the provision of satisfactory facilities for the collection and disposal of the solid wastes or refuse. Of the three municipal functions, least progress has been made in the solution of the problem of refuse collection and disposal.

Doubtless one reason why the refuse problem is still so vexing in most communities is because the collections, of necessity, must be intermittent, and yet the system must function smoothly and without interruption. The public sewerage system, on the other hand, is available constantly, at all hours of the day or night, and in consequence, there is no problem of collection here at all. The only problem that exists is that of proper disposal. With refuse, proper receptacles must be provided in each home; they must be placed or kept at convenient locations on days when collections are made; the refuse must then be transported to the point of final disposal; and finally, the wastes must receive adequate final treatment before the municipality is released of its responsibility.

In order to minimize the danger of creating nuisances and to insure satisfactory and economical service to all residents, a municipality should provide an adequate system of collection for all municipal refuse. Where collections are performed by licensed scavengers, or where provision for municipal collections has not been made, collections are apt to be irregular, with the result that many nuisances are created. Under such conditions popular complaints are quite general.

Composition of refuse. — Municipal refuse is composed of public, trade, market, stable, and house refuse. Public refuse is made up of street manure, street sweepings, street dust, leaves, droppings from wagons, snow, large dead animals, and the contents of public catch basins.

Trade refuse is composed of steam ashes, dry factory wastes, slaughterhouse wastes, the rubbish from office buildings and factories, and the cleanings from private catch basins. Market refuse consists of market garbage, the rubbish and cleanings from markets, and old boxes and barrels. Stable refuse consists of manure and straw, and the cleanings from stables, including fly maggots.

House refuse is composed of garbage, ashes, rubbish, and occasionally also of night soil. The garbage, which represents the wastes from the kitchen and table, is made up of animal and vegetable matter, and because of its high moisture content is readily putrescible. In addition, garbage may contain tin cans, including the organic matter that has not been removed, and small dead animals. Tin cans, however, should preferably be freed of all organic matter and disposed of with the rubbish.

Ashes contain not only the products resulting from the combustion of coal and wood, but likewise cinders, clinker, slate, broken glass and crockery, bricks and stones, metal fragments and dust.

Rubbish consists of the sweepings from buildings, boxes and barrels, wood, paper, rags, excelsior, straw, leather, rubber, metal ware, and other articles too numerous to mention. Rubbish should not contain anything that is readily putrescible.

Undoubtedly the most objectionable element in house refuse is the garbage, which decomposes readily and gives rise to serious nuisances. For these reasons garbage must be collected at frequent intervals and must be disposed of satisfactorily. Similarly, stable refuse, market garbage, and organic trade refuse must receive the same consideration.

Reasons for refuse collection and disposal. — The reasons that activate the collection and disposal of municipal refuse are somewhat different from those that prompt the treatment of sewage. Refuse is collected for final disposal, first, to promote general cleanliness in the home and in the community; second, because a clean home and a clean community have a beneficial, psychological effect, which is reflected in the general moral tone of the people; and third, because satisfactory refuse collection and disposal eliminates all nuisances and dangers to health resulting from objectionable odors, the breeding of flies, and the maintenance of rats. In addition, frequent collections of refuse minimize the fire hazard in the home, factory, store, and office building.

Methods of refuse collection. — Refuse collections may be either on the "separate" plan or the "combined" plan. In Europe, where final disposal of municipal refuse is invariably by incineration, refuse collections are always on the combined plan. Local nuisances resulting from decomposing garbage are thus greatly reduced. In the United States, however, where garbage often receives treatment apart from other forms of refuse, the separate system of collection is largely in vogue. The system of collection in use in any community must depend therefore on the final method of disposal. Where garbage is fed to hogs, or treated by reduction, fermentation, or burial, a separate system of collection must always be employed.

Where garbage is collected separately it should be collected daily from hotels, restaurants, lunch rooms, and large apartment houses. In residential districts, three collections per week give satisfactory results. If necessary, two collections per week during the winter may be employed. This arrangement insures the freshness of the garbage; it eliminates or minimizes the possibilities of odors and the dangers from flies and rodents; and it does not overtax the domestic storage capacity for garbage which is ordinarily provided. It is needless to say that garbage should be stored in water-tight, covered containers, and should not be exposed unnecessarily during the period of collection.

In northern communities, where the winters are long and coal is still employed extensively as a fuel, it is necessary to provide for frequent collections of ashes. In the larger cities collections may be as frequent as two or three times a week, especially from the hotels and large apartments; but in purely residential districts a single collection each week usually proves very satisfactory.

While rubbish is non-putrescible, it is bulky and combustible, and its storage in the home for any length of time represents a nuisance and a fire hazard. The situation is especially aggravated where regular municipal collections are not provided and where rubbish is collected only during spring clean-up campaigns. However, if rubbish can be collected simultaneously with ashes, where frequent collections are provided, the situation is quite satisfactory.

Refuse collection and disposal, an engineering problem. — The collection and disposal of municipal refuse is essentially an engineering problem and should therefore be placed under the direction of

the city engineer, the commissioner of public works, or the director of the municipal refuse department, if one exists in the community. It should never be placed under the health department, as refuse collection and disposal is a problem of sufficient magnitude to require a special division or department in the municipal administrative machinery. If it is included in the health department it serves only to impede effective and important public health work, and it does not receive the technical care and consideration that are essential for satisfactory results.

Composition of garbage. — Garbage is extremely variable in its composition and its specific nature is determined by such factors as the habits, wealth, and economy of the population, and the season of the year. The amount of garbage per capita per year varies from 100 to 375 pounds, the average being about 200 pounds, or 0.6 pound per capita per day, exclusive of Sundays when collections are not made. There is also a seasonal variation in the quantity of garbage, the summer contribution in a metropolitan community being greatest. Municipal garbage usually contains from 70 to 80 per cent water, from 16 to 30 per cent animal and vegetable solids, and from 2 to 7 per cent of non-combustible material. The dry solid matter contains from 6 to 9 per cent of grease, from 1.5 to 2.5 per cent of phosphoric acid, and from 1.5 to 4 per cent nitrogen. It is the presence of the grease, phosphoric acid and nitrogen in garbage which gives it economic value.

Composition of ashes and rubbish. — Ashes contain considerable quantities of unburned coal, usually less than 20 per cent by weight, and in northern communities amounts to about 0.8 ton per capita per year exclusive of factory and industrial ashes. In southern communities the amount may be as low as 0.1 ton per capita per year. With the increasing use of gas and oil for domestic heating, the amount of ashes is destined to decrease. The amount of municipal rubbish usually varies from 0.1 to 0.6 pound per capita per day.

Requirements of satisfactory collections. — Efficient and economical collection of municipal refuse requires that the solid wastes should be collected in suitable vehicles, that the garbage and other organic refuse should be thoroughly protected against flies and the elimination of odors during transit, and that the haul to the place of disposal should be short. To this end a collecting station should be available in each section of a large city from which the refuse may

be removed in bulk to the place of final disposal. Sometimes, however, the refuse is disposed of at these stations by local incineration.

Disposal of manure and dead animals. — Manure should be removed at least once a week and used as a fertilizer. Adequate provision should also be made for the removal and proper disposal of dead animals and organic trade refuse. Where reduction is the method employed for the final disposal of garbage the dead animals of the community may also be disposed of in this way.

Methods of refuse disposal. — The methods of disposal for municipal refuse may be enumerated as follows:

1. Dumping.
2. Burial.
3. Use as a fertilizer.
4. Feeding to animals.
5. Fermentation.
6. By grinding and disposal with the municipal sewage.
7. Incineration.
8. Reduction.

Dumping. — Dumping may be employed either on land or at sea. Both methods of disposal are highly objectionable, especially for organic wastes and even for rubbish. New York has only recently been enjoined from dumping its garbage at sea and has had to build incinerators for the treatment of these wastes. Ashes may be disposed of by dumping, and in most communities are used for filling in low and swampy places.

Burial and use as a fertilizer. — Burial is employed only where this method may improve the quality of the soil. Only garbage, manure, and night soil are disposed of in this way. Where this method is employed the organic wastes should be put in trenches from 18 to 30 inches in depth, and spread in a layer 6 to 12 inches thick, and then covered with 6 to 12 inches of soil. In this way, and after several years, the organic matter will be completely mineralized through the agency of bacteria, in the presence of air. This method of disposal is not used to any extent in this country.

Feeding to animals. — Garbage is the only element in refuse that can be disposed of in this way and the hog is the only animal that should be employed where this method of disposal is in use. It is essential that the garbage should be fresh, *i.e.*, not more than 2 days old in summer, nor more than 4 days in winter. It should

also be free of broken glass, broken crockery, safety razor blades, and other inedible substances. In order to avoid serious nuisances at the piggery special feeding platforms or troughs of impervious material such as concrete should be provided, and the remains after each feeding should be collected and buried. Feeding platforms should also be washed thoroughly after each feeding. All hogs on the farm should be immunized against hog cholera. If these precautions are observed garbage disposal by feeding to hogs can be made both economically remunerative and hygienically satisfactory, and a waste product transformed into good human food.

Much has been said and written against this method of garbage disposal, but all objections may usually be explained on the basis of poor management, rather than because of any inherent defect in the process itself. In New England it is still used very extensively. Most of the small communities still employ this method of treatment, and even some of the larger ones, including Worcester, Somerville, Fall River, Lowell, Lawrence, Cambridge, and Newton. Grand Rapids has disposed of its garbage profitably by feeding to hogs for years, and at present (1934), the city of Los Angeles, with a population of over 1,500,000, is employing this method. In general, the larger cities, *i.e.*, those having a population in excess of 100,000, employ incineration or reduction, as garbage disposal by feeding to hogs in such communities usually requires enormous tracts of land and a great many animals. However, where it can be employed satisfactorily there is no reason why it should not be used.

Fermentation. — This method is applicable to garbage and other organic wastes, and is known as the Beccari system. It has been developed and used most extensively in Italy, but it also has had a limited application in the United States. In brief it consists of the following procedure. The non-fermentable materials such as glass, metals, bones, rags, etc., are removed, and the garbage is put into concrete cells, each of which has a capacity of about 20 cubic yards. The garbage is moistened with liquid obtained from a cesspool, and the cell is closed for six weeks. Openings near the ground, and roof vents, make for satisfactory ventilation and for the aërobic bacterial oxidation of the organic matter in the garbage. Odor nuisances, however, occur frequently. At the end of 6 weeks the garbage has been transformed into a stable, brown, humus-like

material, which has fertilizer value. It is removed, screened, and sold for fertilizer.

Disposal with sewage. — This method is applicable for garbage only where a satisfactory sewage treatment plant is available. The garbage is ground up and fed into the municipal sewage supply in amounts, insufficient to interfere with the efficiency of operation of the sewage treatment plant. The process has only a limited applicability at the present time.

Incineration. — From a sanitary point of view, this method of refuse disposal is undoubtedly the best, for all combustible matter, including any disease-producing bacteria that may be present, are destroyed. Just at present, incineration seems to be very popular in the United States. Where incineration is employed, a combined system of collection is made possible and the rubbish serves as part of the fuel required to destroy the garbage and other organic refuse. Theoretically, incineration yields salable materials in the form of heat and ashes, but recent information makes it clear that incinerating plants rarely obtain any revenue from their operation. The heat is wasted and the ashes and residue are disposed of by dumping.

Incineration is employed on mixed refuse or on combustible rubbish alone. New York plans to destroy mixed refuse by incineration and Providence at present is also treating mixed refuse in this way. Where garbage or mixed refuse is destroyed by incineration, the cost is high. While accurate data are difficult to obtain, it seems fair to conclude from the data that are available that the average cost of incineration today is about $1.00 per ton of refuse. Sometimes it is much higher, and in other instances it is less.

Both incineration and reduction have been responsible for the production of odor nuisances which have prejudiced popular opinion against them. In fairness, however, it must be said that both types of treatment have been operated near the center of large cities without creating any nuisance. In such cases, however, the supervision has been very efficient. The elimination of nuisances resulting from refuse disposal depends in a large measure on the efficiency and technical skill of operation. Without such supervision the best designed plant is destined to failure.

Nuisances resulting from incineration are due to the escape of inadequately oxidized gases and solid particles. In order to prevent

objectionable conditions all gases should be heated at a temperature of at least 1250° to 1300° F. before they are released through the chimney. Soluble gases which are objectionable may be removed by washing.

Reduction. — This method of treatment is applicable to garbage and dead animals, and is employed to a considerable degree in the larger cities of the United States. In Europe, where the garbage is not as rich in grease or nitrogen as it is in the United States, and where there is less waste of food, reduction is rarely, if ever, employed. Reduction necessitates a separate system of collection, but it holds out the hope of a definite economic return which will make the treatment process profitable, or at least able to pay for itself. During the World War, when glycerin was in great demand for the manufacture of explosives, garbage reduction was in great favor, for it yielded grease which could be transformed into glycerin and the financial return made the treatment process very profitable. At present (1934), however, the price for garbage grease is exceedingly low and garbage reduction is far from being profitable. Garbage grease is also used for the manufacture of soap, candles, and perfumes.

Reduction may be defined as the treatment of garbage for the removal of grease, the separation and disposal of the water in the garbage, and the preparation of the dry residue or tankage for use as a fertilizer, or as a base for animal food. There are more than a dozen different types of reduction processes, but in each case the grease is removed by drying and pressing, or by cooking. The latter is usually done in the presence of a solvent like naphtha. Cooking is less likely to produce an odor nuisance than drying, but it has instead a fire hazard of considerable magnitude because of the inflammability of the naphtha. Where reduction is employed the rubbish is sometimes burned at the plant to assist in generating the heat or steam necessary to carry on the treatment process. It is important that the garbage should be treated almost as soon as it arrives at the plant in order to minimize the possibility of nuisances.

The gases resulting from this process are the most difficult portion of the wastes to dispose of satisfactorily and often give rise to odor nuisances. They contain certain volatile substances such as ammonia, phosphine, acetic acid, carbon dioxide, sulphur compounds, and burnt carbohydrates. The insoluble gases may be

readily deodorized by oxidation, by passing them through a hot fire at a temperature of at least 1250° to 1300° F. The soluble gases can be removed by washing, and the wash water allowed to flow into the sewer. Insoluble sulphur compounds can be removed by heat treatment in combination with washing. The heat transforms the sulphur to sulphur dioxide, which is soluble in water, and the washing of this gas removes it.

Many reduction plants are municipally owned and operated. Others are owned and operated under private auspices. Among the former are the plants at Cleveland, Columbus, Dayton, Akron, Schenectady, Chicago, Washington, Indianapolis, Rochester, and Syracuse. Among the latter are the plants at Boston, Cincinnati, Pittsburgh, Detroit, Toledo, Philadelphia, and Bridgeport. Reduction must be considered a valuable and potentially remunerative method of treatment for garbage in the larger American communities, but if it is to give satisfactory results and operate without creating nuisances, it must be placed under competent and trained engineering supervision.

CHAPTER IX

WATER AS A VEHICLE OF INFECTIOUS DISEASE

Inasmuch as sewage may contain any or all of the infectious materials from diseased animal bodies, and inasmuch as it is a liquid readily miscible with water — being itself hardly more than very dirty water — it is perhaps not surprising that the germs of disease have often found access to wells, springs, reservoirs, and streams, from which water was later drawh for drinking purposes with tragic results.

Drinking water as a vehicle of disease. — It has been shown in a previous chapter that while infectious materials may sometimes enter the body through the skin, the more common and easier avenues are those of the alimentary, respiratory, and genito-urinary tracts. Of all the substances admitted into the alimentary canal, the most abundant, and perhaps the most trusted, is water. The "cup of cold water" has long stood as the symbol of charity; and yet, from the sanitary point of view, there is little or no doubt that water is one of the most potentially dangerous vehicles of disease which passes through the gates leading into the human body.

Theoretically, water that is chemically pure, should, of course, contain no infectious materials, although it is an interesting fact that in laboratory experiments it is possible to introduce into distilled water a considerable number of pathogenic bacteria without producing any effect upon the water discoverable by the most refined chemical analysis. Again, it is quite possible, in laboratory experiments, to mingle with a specimen of water millions of the germs of typhoid fever or Asiatic cholera without effecting perceptibly its bright and attractive appearance. With these facts in mind it becomes comparatively easy to understand that water may appear bright and attractive to the eye and be acceptable to the palate, while yet containing myriads of disease germs. It should not be forgotten, however, that what has been stated is true only of laboratory experiments, and rarely, if ever, does this happen under natural conditions.

Natural waters, such as those of springs and wells, brooks and other streams from uninhabited districts, should ordinarily be free of infectious materials; and such waters, although they may contain mud, or various vegetable and even animal matters, are commonly described as "pure." But it is very different with natural waters which have been exposed to pollution, especially by sewage; for if sewage in any form finds its way into drinking waters, these are more than likely to prove a convenient vehicle for the conveyance of infectious materials into the human body. Even if sewage has been somewhat purified by dilution or some other treatment, its presence in waters used for drinking properly constitutes a source of anxiety, the precise danger involved depending in any special case upon the degree of purification which it has undergone.

Diarrheal diseases and drinking water. — A little reflection will show that while diseases of the skin, the throat, the lungs, the nose, etc., are accompanied by eruptions, exudations, expectorations, or other discharges which may find their way into sewage, these are usually insignificant in amount in comparison with the bowel discharges. It is not surprising, therefore, to learn that diseases affecting the alimentary canal and especially the intestine, particularly if accompanied by diarrhea, are most conspicuous among the diseases conveyed by sewage-polluted drinking water. It is now well established that certain bowel diseases, such as typhoid fever and Asiatic cholera, are readily conveyed by drinking water, and numerous epidemics of these diseases have been traced to infected water supplies; but there is very little evidence of the conveyance of diseases of the skin, throat, lungs, and nose by this particular vehicle, even though tubercle bacilli have been isolated from the sewage of tuberculosis sanatoria, and other pathogens could doubtless be isolated from the sewages of communicable disease hospitals.

Typhoid fever and Asiatic cholera. — These two diseases, and especially typhoid fever, are of preëminent importance and interest to the student of sanitary science, and for this reason a short account of their natural history will be given at this point as a preface to their further consideration. As long ago as 1874 expert opinion had concluded that "the existence of specific poisons capable of producing cholera and typhoid fever is attested by evidence so abundant and strong as to be practically irresistible.

These poisons are contained in the discharges from the bowels of persons suffering from these diseases." *

Typhoid fever is so called because it resembles, and was not formerly distinguishable from, typhus fever, otherwise known as "ship," "jail," or "spotted" fever. It is characterized by a slow and insidious onset during a period lasting about two weeks, during which the patient generally suffers from severe frontal headache, often having in addition backache, nosebleed, diarrhea, and a general loss of strength, which finally, in severe cases, compels him to take to his bed. By this time active fever is well established, the temperature ranging from 100° to 105° F. or even higher, and characterized by a daily rise in the evening and a fall in the morning. During the period of active sickness, which usually lasts from four to eight weeks, delirium sometimes occurs, and other serious symptoms make their appearance. It is a characteristic of the disease, and one which distinguishes it from typhus fever, that in typhoid fever the small intestine undergoes more or less extensive and dangerous ulcerations; and inasmuch as these ulcers burrow into the wall of the intestinal tube, they may either perforate it, allowing fecal matters to enter the peritoneal cavity and causing speedy death from peritonitis, or they may involve important blood vessels, which becoming disintegrated cause profuse hemorrhages, often likewise followed by speedy death.

Owing to the fact that the lower animals are not susceptible to typhoid fever, it has never been possible, as yet, to establish with absolute certainty the causal relationship of the typhoid fever germ with typhoid fever. At the same time there is a very general agreement that the so-called Koch-Eberth-Gaffky bacillus is, in all probability, the real and specific cause of the disease. In recent years various accidental laboratory infections have served to confirm this probable relationship between the typhoid bacillus and typhoid fever.

The commonly accepted theory of the causation of typhoid fever is that the specific bacilli, making their way into the alimentary canal in such vehicles as water, milk, and solid food, survive the journey through the stomach, and finding themselves in the intestine, multiply there and produce their own specific toxin, to the absorption of which are due the earlier symptoms of the disease. Simultaneously, the guardian membranes of the alimentary tract

* *Rivers Pollution Commission of 1868, Sixth Report*, London, 1874, p. 427.

are weakened or otherwise damaged, so that their usual resistance is somewhat enfeebled, and the bacilli make their way through them into the tissues of the body proper. Of all the tissues the spleen seems to be particularly affected, resulting in marked enlargement, and it is from this organ that the typhoid bacilli are most easily recovered.

The bowel discharges of typhoid fever patients naturally contain large numbers of the germs of typhoid fever, and if these discharges find their way into sewage, such sewage must be not only polluted with the ordinary bowel discharges, but is also actually infected with the specific germs of the disease. Furthermore, if this sewage happens to find its way into a water supply, that supply is liable to become a vehicle of disease unless it is purified in some way before it is used for drinking purposes. It should also be observed in passing that the journey from one human intestine to another, may conceivably be very short, very direct, and very quick; and it is also easy to understand that the virulence of the germs may well depend upon the various conditions to which they have been submitted *en route.*

Asiatic cholera is a disease in many respects similar to typhoid fever, but more violent, more rapid, and more fatal. In this case also, owing to the insusceptibility of the lower animals to the disease, it has been impossible to prove absolutely that the *Spirillum* or *Vibrio* of cholera, generally regarded as the cause of the disease, is surely such. Certain experiments, voluntarily made by human beings, and a large amount of circumstantial evidence, have made it highly probable, however, that the germ and the disease are definitely related.

In the case of typhoid fever the presence of typhoid fever bacilli in the bowel discharges of patients suffering from that disease can be demonstrated by bacteriological methods, and the identity of the organisms confirmed in adequate dilution by the Widal agglutination test when a typhoid immune blood is employed. Since the isolation of the typhoid bacillus from a typhoid stool is an uncertain and time-consuming process, the surer Widal agglutination test is today always employed as an aid in the diagnosis of the disease. The blood of the patient is utilized for this purpose together with a laboratory culture of the typhoid bacillus. If the blood contains agglutinins for the typhoid bacillus, the latter, in a hanging drop suspension will be agglutinated or clumped if

mixed with a drop or two of the blood. This can be observed quite readily under the microscope. The test, however, is of no value if the patient has been artificially immunized against typhoid fever.

In the case of Asiatic cholera the number of microörganisms present in the bowel discharges is so enormous that it has been from the start easy to demonstrate their existence and to prove their identity by specific biochemical tests as well as by microscopic examination.

An epidemic of Asiatic cholera traced to a well. The case of the Broad Street (London) pump. — One of the earliest, one of the most famous, and one of the most instructive cases of the conveyance of disease by polluted water is that commonly known as the epidemic of Asiatic cholera connected with a Broad Street (London) well, which occurred in 1854. For its conspicuously circumscribed character, its violence and fatality, and especially for the remarkable skill, thoroughness and success with which it was investigated, it will long remain one of the classical instances of the terrible efficiency of polluted water as a vehicle of disease. As a monument of sanitary research, of medical and engineering interest, and of penetrating inductive reasoning, it deserves the most careful study. No apology, therefore, need be made for giving it here a somewhat extended account.*

(*a*) *The Parish of St. James, Westminster, in 1854.* — The parish of St. James, Westminster (London), occupied in 1854, 164 acres, and contained in 1851, 36,406 inhabitants. It was divided into three subdistricts, viz., those of St. James's Square, Golden Square, and Berwick Street. As will be seen by the map it was situated near a part of London now well known to travelers, not far from the junction of Regent and Oxford streets. It was bounded by May Fair and Hanover Square on the west, by All Souls and Marylebone on the north, St. Anne's and Soho on the east, and Charing Cross and St. Martin's-in-the-Fields on the east and south.

In the cholera epidemics of 1832, 1848–1849, and 1853, St. James's Parish suffered somewhat, but on the average, decidedly less than London as a whole. In 1854, however, the reverse was the case. The Inquiry Committee estimated that in this year

* The complete original report is entitled *Report on the Cholera Outbreak in the Parish of St. James, Westminster, during the Autumn of 1854. Presented to the Vestry by the Cholera Inquiry Committee, July, 1855.* London, J. Churchill, 1855.

"the fatal attacks in St. James's Parish were probably not less than 700," and from this estimate computed a cholera death rate, during 17 weeks under consideration, of 220 per 10,000 living in the parish, which was far above the highest in any other district. In the adjoining subdistrict of Hanover Square the ratio was 9; and in the Charing Cross district of St. Martin's-in-the-Fields (in-

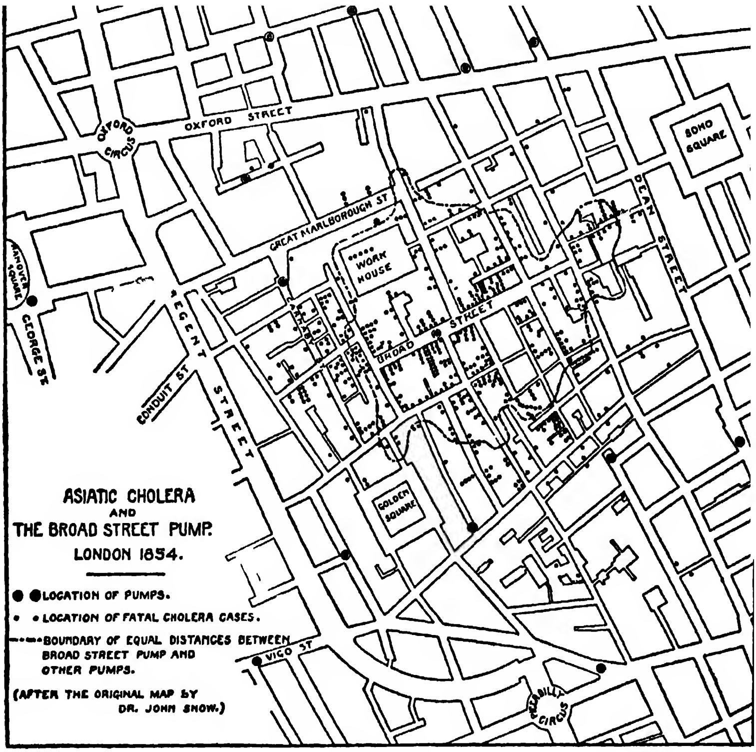


FIGURE 2

cluding a hospital) it was 33. In 1848–1849 the cholera mortality in St. James's Parish had been only 15 per 10,000 inhabitants.

(*b*) *The search for the source of the epidemic.* — Within the parish itself the disease in 1854 was very unequally distributed. In the St. James's Square district the cholera mortality was only 16 per 10,000, while in the Golden Square district it was 217, and in the Berwick Street district, 212. It was plain that there had been a special cholera area, a localized, circumscribed district. This was

eventually minutely studied in the most painstaking fashion as to population, industries, previous sanitary history, meteorological conditions, and other general phenomena common to London as a whole; with the result that it was found to have shared with the rest of London "a previous long-continued absence of rain . . .; a high state of temperature both of the air and of the Thames . . .; an unusual stagnation of the lower strata of the atmosphere, highly favorable to its acquisition of impurity . . .; and although it was impossible . . . to fix the precise share which each of the conditions enumerated might separately have had in favoring the spread of cholera, the whole history of that malady, as well as of the epidemic of 1854, and indeed of the plagues of past epochs, justifies the supposition that their combined operation, either by favoring a general impurity in the air or in some other way, concurred in a decided manner, last summer and autumn (1854), to give temporary activity to the special cause of that disease." * The Inquiry Committee did not, however, rest satisfied with these vague speculations and conclusions. ". . . But, as previously shown in the history of this local outbreak, the resulting mortality was so disproportioned to that in the rest of the metropolis, and more particularly to that in the immediately surrounding districts, that we must seek more narrowly and locally for some peculiar conditions which may help to explain this serious visitation."

Accordingly, special inquiries were made within the district involved in regard to its "elevation of site"; "soil and subsoil" (including an extended inquiry into the history of a "pest-field," said to have been located within this area in 1665–1666, to which some had attributed the cholera of 1854); "surface and ground plan"; "streets and courts"; "density of population"; "character of the population"; "dwelling houses — internal economy as to space, light, ventilation and general cleanliness"; "dust-bins and accumulations in yards, cellars and areas"; "cesspools, closets and house-drains"; "sewers, their waterflow and atmospheric connection"; "public water supply"; and "well-water supply." No peculiar condition or adequate explanation of the origin of the epidemic was discovered in any of these, even after the most searching inquiry, except in the well-water supply. Abundant general defects were found in the other sanitary factors, but

* *Report of Cholera Inquiry Committee*, pp. 38. 39.

nothing peculiar to the cholera area, or, if peculiar, common to those attacked by the disease, could be found excepting the supply of well water.

(*c*) *Suspicion falls upon the Broad Street pump. The investigations of Dr. John Snow.* — At the very beginning of the outbreak, Dr. John Snow, with commendable energy, had taken the trouble to get the number and location of the fatal cases as is stated in his own report:

"I requested permission, on the 5th of September, to take a list, at the General Register Office, of the deaths from cholera registered during the week ending the 2d of September in the subdistricts of Golden Square and Berwick Street, St. James's, and St. Anne's, Soho, which was kindly granted. Eighty-nine (89) deaths from cholera were registered during the week in the three subdistricts. Of these only six (6) occurred on the first four days of the week; four (4) occurred on Thursday, August 31; and the remaining 79 on Friday and Saturday. I considered, therefore, that the outbreak commenced on the Thursday; and I made inquiry in detail respecting the 83 deaths registered as having taken place during the last three days of the week.

"On proceeding to the spot I found that nearly all the deaths had taken place within a short distance of the pump in Broad Street. There were only ten (10) deaths in houses situated decidedly nearer to another street pump. In five (5) of these cases the families of the deceased persons told me that they always sent to the pump in Broad Street, as they preferred the water to that of the pump which was nearer. In three other cases the deceased were children who went to school near the pump in Broad Street. Two of them were known to have drunk the water, and the parents of the third think it probable that it did so. The other two deaths beyond the district which the pump supplies represent only the amount of mortality from cholera that was occurring before the eruption took place.

"With regard to the 73 deaths occurring in the locality belonging, as it were, to the pump, there were 61 instances in which I was informed that the deceased persons used to drink the water from the pump in Broad Street, either constantly or occasionally. In six (6) instances I could get no information, owing to the death or the departure of every one connected with the deceased individuals;

* *Report of Cholera Inquiry Committee*, pp. 100 et seq.

and in six (6) cases I was informed that the deceased persons did not drink the pump water before their illness.

"The result of the inquiry consequently was that there had been no particular outbreak or increase of cholera in this part of London, except among the persons who were in the habit of drinking the water of the above-mentioned pump well.

"I had an interview with the Board of Guardians of St. James's Parish on the evening of Thursday, 7th of September, and represented the above circumstances to them. In consequence of what I said the handle of the pump was removed on the following day. . . .

"The additional facts that I have been able to ascertain are in accordance with those above related; and as regards the small number of those attacked who were believed not to have drunk the water from the Broad Street pump, it must be obvious that there are various ways in which the deceased persons may have taken it without the knowledge of their friends. The water was used for mixing with spirits in some of the public houses around. It was used likewise at dining rooms and coffee-shops. The keeper of a coffee-shop which was frequented by mechanics and where the pump water was supplied at dinner time, informed me on the 6th of September that she was already aware of nine of her customers who were dead."

On the other hand, Dr. Snow discovered that while a workhouse (almshouse) in Poland Street was three-fourths surrounded by houses in which cholera deaths occurred, out of 535 inmates of the workhouse only five (5) cholera deaths occurred. The workhouse, however, had a well of its own in addition to the city supply, and never sent for water to the Broad Street pump. If the cholera mortality in the workhouse had been equal to that in its immediate vicinity, it should have had fifty deaths.

A brewery in Broad Street employing seventy workmen was entirely exempt, but having a well of its own, and allowances of malt liquor having been customarily made to the employees, it appeared likely that the proprietor was right in his belief that resort was never had to the Broad Street well.

It was quite otherwise in a cartridge factory at No. 38 Broad Street, where about two hundred work-people were employed, two tubs of drinking water having been kept on the premises and always filled from the Broad Street well. Among these employees,

eighteen died of cholera. Similar facts were elicited for other factories on the same street, all tending to show that in general those who drank the water from the Broad Street well suffered either from cholera or diarrhea, while those who did not drink that water escaped. The whole chain of evidence was made absolutely conclusive by several remarkable and striking cases like the following:

"A gentleman in delicate health was sent for from Brighton to see his brother at No. 6 Poland Street, who was attacked with cholera and died in twelve hours, on the 1st of September. The gentleman arrived after his brother's death and did not see the body. He only stayed about twenty minutes in the house, where he took a hasty and scanty luncheon of rump steak, taking with it a small tumbler of cold brandy-and-water, the water being from Broad Street pump. He went to Pentonville and was attacked with cholera on the evening of the following day, September the 2d, and died the next evening.

"The deaths of Mrs. E—— and her niece, who drank the water from Broad Street at the West End, Hampstead, deserve especially to be noticed. I was informed by Mrs. E——'s son that his mother had not been in the neighborhood of Broad Street for many months. A cart went from Broad Street to West End every day, and it was the custom to take out a large bottle of the water from the pump in Broad Street, as she preferred it. The water was taken out on Thursday, the 31st of August, and she drank of it in the evening and also on Friday. She was seized with cholera on the evening of the latter day and died on Saturday. A niece who was on a visit to this lady also drank of the water; she returned to her residence, a high and healthy part of Islington, was attacked with cholera, and died also. There was no cholera at this time either at West End or in the neighborhood where the niece died. Besides these two persons only one servant partook of the water at West End, Hampstead, and she did not suffer, or, at least, not severely. She had diarrhea."

Dr. Snow's inquiry into the cases of cholera which were nearer other pumps showed that in most the victims had preferred, or had access to, the water of the Broad Street well, and in only a few cases was it impossible to trace any connection with that pump. Finally, Dr. Snow made a statistical statement of great value which is here given in its original form.

TABLE 9

THE BROAD STREET (LONDON) WELL AND DEATHS FROM ASIATIC CHOLERA NEAR IT IN 1854

DATE		NUMBER OF FATAL ATTACKS	DEATHS	DATE		NUMBER OF FATAL ATTACKS	DEATHS
August	19	1	1	September	11	5	15
"	20	1	0	"	12	1	6
"	21	1	2	"	13	3	13
"	22	0	0	"	14	0	6
"	23	1	0	"	15	1	8
"	24	1	2	"	16	4	6
"	25	0	0	"	17	2	5
"	26	1	0	"	18	3	2
"	27	1	1	"	19	0	3
"	28	1	0	"	20	0	0
"	29	1	1	"	21	2	0
"	30	8	2	"	22	1	2
"	31	56	3	"	23	1	3
September	1	143	70	"	24	1	0
"	2	116	127	"	25	1	0
"	3	54	76	"	26	1	2
"	4	46	71	"	27	1	0
"	5	36	45	"	28	0	2
"	6	20	37	"	29	0	0
"	7	28	32	"	30	0	0
"	8	12	30	Date unknown		45	0
"	9	11	24				
"	10	5	18	Total		616	616

(*d*) *The Rev. Mr. Whitehead's detailed studies of Broad Street and its pump.* — In addition to the original and general inquiry conducted from the time of the outbreak by Dr. Snow, the Rev. H. Whitehead, M.A., curate of St. Luke's in Berwick Street, and like Dr. Snow, a member of the Cholera Inquiry Committee, whose knowledge of the district both before and during the epidemic, owing to his official position, gave him unusual advantages, made a most elaborate and painstaking house-to-house investigation of one of the principal streets affected, viz., Broad Street itself. Mr. Whitehead's report, like that of Dr. Snow, is a model of careful and extended observation and study, cautious generalizing and rigid verification. It is an excellent instance of inductive scientific inquiry by a layman in sanitation. Mr. Whitehead found the number of houses on Broad Street, 49; the resident householders, 35; the total number of resident inhabitants, 896; the total number of deaths among these, 90. Deaths among non-

residents (workmen, etc.) belonging to the street, 28. Total deaths chargeable to this street alone, 118. Only 10 houses out of 49 were free from cholera.

Mr. Whitehead's detailed investigation was not made until the spring of 1855, but in spite of this fact it supplied most interesting and important confirmatory evidence of Dr. Snow's theory that the Broad Street well was the source of the epidemic. Mr. Whitehead, moreover, went further than Dr. Snow, and endeavored to find out how the well came to be infected, why its infectious condition was so limited as it appeared to have been, and to answer various other questions which occurred in the course of his inquiry. As a result, he concluded that the well must have been most infected on August 31; that for some reason unknown a partial purification began on September 2, and thereafter proceeded rapidly. There was some evidence that on August 30 the water was much less infected than on the 31st, so that its dangerous condition was apparently temporary only. He further discovered that in the house No. 40 Broad Street, which was the nearest house to the well, there had been not only four fatal cases of cholera contemporaneous with the epidemic, but certain earlier cases of an obscure nature which might have been cholera, and that dejecta from these had been thrown without disinfection into a cesspool very near to the well. On his reporting these facts in April, 1855, to the main committee, Mr. J. York, secretary and surveyor to the committee, was instructed to survey the locality and examine the well, cesspool, and drains at No. 40 Broad Street.

(*e*) *Survey and description of the Broad Street well and its surroundings.* — Mr. York's report revealed a startling condition of affairs. The well was circular in section, 28 ft. 10 in. deep, 6 ft. in diameter, lined with brick, and when examined contained 7 ft. 6 in. of water. It was arched in at the top, dome fashion, and tightly closed at a level 3 ft. 6 in. below the street, by a cover occupying the crest of the dome.

The bottom of the main drain of the house No. 40 Broad Street lay 9 ft. 2 in. above the water level, and one of its sides was distant from the brick lining of the well only 2 ft. 8 in. It was "constructed on the old-fashioned plan of a flat bottom, 12 in. wide, with brick sides rising about 12 in. high, and covered with old stone. As this drain had but a small fall, or inclination outward to the main sewer, the bottom was covered with an accumulation of soil de-

posit about 2 in. thick; and upon clearing this soil away the mortar joints of the old stone bottom were found to be perished, as was also all the jointing of the brick sides, which had brought the brickwork into the condition of a sieve, and through which the house drainage water must have percolated for a considerable period. . . .

"After opening back the main drain, a cesspool intended for a trap, but misconstructed, was found in the area, 3 ft. 8 in. long, by 2 ft. 6 in. wide, and 3 ft. deep; and upon or over a part of this cesspool a common open privy (without water supply), for the use of the house, was erected, the cesspool being fully charged with soil. This privy was formed across the east end of the area, and upon removing the soil the brickwork of the cesspool was found to be in the same decayed condition as the drain, and which may be better comprehended by stating that the bricks were easily lifted from their beds without any, the least, force; so that any fluid could readily pass through the work, or, as was the case when first opened, over the top course of bricks of the trap, into the earth or made ground immediately under and adjoining the end wall eastward, this surface drainage being caused by the accumulation of soil in, and the misconstruction of, the cesspool. . . .

"Thus, therefore, from the charged condition of the cesspool, the defective state of its brickwork, and also that of the drain, no doubt remains upon my mind that constant percolation, and for a considerable period, had been conveying fluid matter from the drains into the well; but lest any doubt should arise upon this subject hereafter, I had two spaces of the brick steining, 2 ft. square each, taken out of the inside of the well — the first 13 ft. deep from the level of the street paving, the second 18 ft. deep, and a third was afterward opened still lower, when the washed appearance of the ground and gravel fully corroborated the assumption. In addition thereto, the ground was dug out between the cesspool and the well to 3 ft. below the bottom of the former, and its black, saturated, swampy condition clearly demonstrated the fact, as did also the small furrowed appearance of the underlying gravel observed from the inside of the well, from which the fine sand had been washed away during the process of filtration." *

It was thus established, as clearly as can be done by circum-

* *Report of J. York, Secretary and Surveyor to the Cholera Inquiry Committee.*

stantial evidence, that the great epidemic in St. James's Parish, Westminster, London, in 1854, was caused by the polluted water of the Broad Street well, which for a very few days was probably

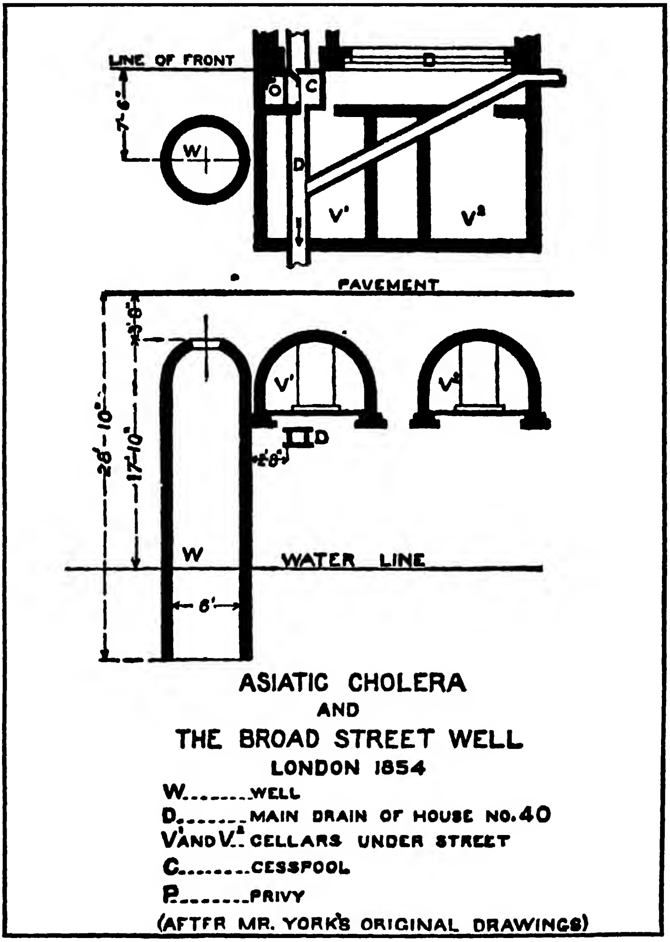


FIGURE 3

infected with cholera germs. It is much less clear how the well became infected, but it seems probable that the dejecta of a cholera patient found tolerably direct access to the well from the cesspool or drain of a house near by. There is no evidence whatever that the germs multiplied in the well, but rather much evidence that they rapidly died out.

That the water had long been polluted, there can be no doubt. One consumer spoke of it as being "offensive" in taste or odor at the time of the epidemic. It is instructive to note that mere pollution seems to have done no obvious harm. Specific infection, however, produced Asiatic cholera.

The transportation and diffusion by contagion of typhoid fever; exemplified in its occurrence at North Boston, Erie County, N.Y.* — The French physician, Louis, had shown in 1829 that typhoid fever was a separate and distinct disease from typhus fever. At the same time there was a growing conviction among the more progressive physicians that typhus fever was spread by contagion, but nearly everybody held that typhoid fever was not. However, a few courageous individuals were beginning to maintain rather cautiously that typhoid fever was also spread by contagion, and accordingly, a scientific controversy was going on at the time, each side trying to prove its case.

"Under the circumstances," Dr. Flint says, "an apology is not needed for inviting the attention of the medical reader to facts which appear to bear with remarkable cogency on this mooted question. In this remark I have reference to the occurrence of a series of cases of typhoid fever at a place known as North Boston, County of Erie, N.Y., in the autumn of 1843, a report of which was communicated by the writer for the *American Journal of Medical Sciences* for July, 1845.

"Were it proposed to devise a series of experiments the most unobjectionable and complete, in order to test the communicability of a particular form of disease, no better plan could be adopted than to introduce a case or cases of the disease into districts where it was not at the time prevailing, and to procure free exposure on the part of some of those residing in the district. The experiment would be more satisfactory if the disease thus introduced was not indigenous in that locality, and had never, or at least not for many years before, been known to occur. To render the experiment as perfect as possible by divesting it of any moral influence, it should be made without the knowledge of those who were to be the subjects. In other words, the character of the disease should be unknown, and the persons coming in contact with it should be wholly unconscious of any exposure to contagion. Now, if under all these

* *Clinical Reports on Continued Fever*, by Austin Flint, M.D., published by Lindsay and Blakiston, Philadelphia, in 1855.

circumstances, a large proportion of those of the inhabitants of the district who had been brought into contact with the disease, are attacked simultaneously, or in quick succession, and thus a new and hitherto unknown affection is suddenly developed, which spreads rapidly over a limited circuit, affecting those only who had been in habits of intercourse with the imported case or with the persons who were subsequently attacked, others residing in the same district, but not brought into contact with the disease, uniformly escaping — what would be the logical deduction from the facts? In the absence of all evidence of epidemic or endemic agencies, contagion offers the only adequate explanation. The laws of probabilities would not authorize the supposition that the events depended on mere coincidence. Stronger proof of communicability certainly could not be obtained by any other process of investigation. To undertake such an experiment would neither be practicable nor justifiable. The same combination of circumstances, however, not involving premeditation or design, will be found in the history of the development and diffusion of typhoid fever at North Boston in 1843."

Briefly, the facts of the epidemic as determined on investigation were these. North Boston in 1843 was a very small community, about "an hundred rods in diameter," composed of 43 persons distributed among nine families. The community was "about 18 miles from Buffalo and 12 miles from the lake shore, at a considerable elevation above the level of the lake." Up to the time of the epidemic the health of the community had been excellent, and typhoid fever was an unknown disease.

"On the 21st of September a young man from Warwick, Massachusetts, being on a journey westward, took lodgings at the tavern, kept by a man named Fuller. He had been ill for several days, and had kept on his journey until he felt unable to proceed farther. He remained at the tavern and died on the 19th of October." There was no question that he was suffering from typhoid fever, and the clinical and autopsy evidence obtained on some of the subsequent cases that developed confirms the identity of this disease. The first local resident attacked was the son of Fuller, the innkeeper, aged 16 years. He was attacked on the 14th of October, twenty-three days after the arrival of the stranger. Between then and December 7, "twenty-eight of the forty-three persons comprising the little community at North Boston, all of them,

under 30, were attacked with fever, and in ten instances the disease proved fatal." It was evidently one of the most devastating epidemics of typhoid fever on record.

Only three families in the little settlement escaped. One of these named Stearns, lived in a house only four rods from the tavern, part of which was occupied by Evi Fuller, a son of the innkeeper. Besides Mr. Stearns and his wife, there were four children, and all escaped the disease. The other two families, consisting of eleven people, lived about 40 rods away from the settlement. One of these families had its own water supply, and the other probably did too, although no specific mention of the fact is made in the report. Of the other seven families in the community, who lived very close to each other, only one, the Stearns family, escaped.

Between the Stearns and Fuller families there had been a bitter feud of long standing, and the two families were not on speaking terms with each other and did not have any social intercourse. "Up to a short time before the sickness occurred, the family of Stearns had been supplied with water from Fuller's well, as were all the other families in the immediate vicinity of the inn; but owing to the hostility between the Fuller and Stearns families, the privilege of drawing water from Fuller's well had been refused to Stearns, so that he was obliged to dig out and deepen an old well of his own." The fact that the disease occurred only among those families that used Fuller's well, and the knowledge of the hostility between Fuller and Stearns, led to the suspicion that Stearns had poisoned Fuller's well, but subsequent analysis indicated that the charge was without foundation.

The only families reasonably well off in the town were those of Fuller, Stearns, and the two that lived forty rods away. The others were dependent on Fuller even for food, were constantly at Fuller's inn, used his well water, and were on friendliest relations with Fuller and his family. Furthermore, because of the feud between Fuller and Stearns, these families likewise had no social intercourse with Stearns.

From the foregoing facts it is impossible to state with certainty the exact mode of transmission of this disease. That it may have been transmitted by Fuller's well water which had become infected in some way, and which was used in common by all the families in which cases occurred, is apparent; but the fact that all the families had frequent social intercourse, and that they obtained

food at Fuller's inn regularly, makes it possible that the food had become infected in the process of preparation and handling, and that the disease was transmitted in that way. In any event the epidemic indicates that the disease was transmitted in some way among those who were in daily contact with each other, and since it is one of the earliest studies lending support to the view that typhoid fever is an infectious disease and is spread by contact in some form, it is justifiable and proper to include this account here.

An epidemic of typhoid fever in Lausen, Switzerland, due to an infected ground water or spring. — The first water-borne epidemic of typhoid fever to attract universal attention was that which occurred in Lausen, Switzerland, in 1872; and because of certain peculiar conditions connected with it, and its influence upon the theory and practice of water purification by filtration, it deserves the careful consideration of all students of sanitation.

The epidemic occurred in the little village of Lausen in the canton of Basel in Switzerland in August, 1872. Lausen was a well-kept village of 90 houses and 780 inhabitants, and had never, so far as known, suffered from a typhoid epidemic. For many years it had not had even a single case of typhoid fever, and it had escaped the cholera even when the surrounding country suffered from it. Suddenly, in August, 1872, an outbreak of typhoid fever occurred, affecting a large part of the entire population.

A short distance south of Lausen was a little valley, the Fürlerthal, separated from Lausen by a hill, the Stockhalden, and in this valley, on June 19, upon an isolated farm, a peasant, who had recently been away from home, fell ill with a very severe case of typhoid fever, which he had apparently contracted during his absence. In the next two months there occurred three other cases in the neighborhood — a girl, and the wife and son of the peasant.

No one in Lausen knew anything of these cases in the remote and lonely valley, when suddenly, on August 7, ten cases of typhoid fever appeared in Lausen, and by the end of nine days, fifty-seven cases. The number rose in the first four weeks to more than one hundred, and by the end of the epidemic in October to about 130, or 17 per cent of the population. Besides these, fourteen children who had spent their summer vacation in Lausen fell ill with the same disease in Basel. The fever was distributed quite evenly throughout the town, with the exception of certain houses which derived their water from their own wells and not from the public

water supply. Attention was thus fixed upon the latter, which was obtained from a well or spring at the foot of the Stockhalden hill on the Lausen side. The well was walled up, covered, and apparently protected, and from it the water was conducted to the village, where it was distributed by several public fountains. Only six houses used their own wells, and in these there was not a single case of typhoid fever, while in almost all the other houses of the village, which depended upon the public water supply, cases of the disease existed. Suspicion was thus directed to the water supply as the source of the typhoid poison, very largely because no other source could well be imagined. A distribution of the disease from the farm through the air was hardly conceivable because houses in the Fürlerthal, although lying upon the same plateau and naturally more accessible through the atmosphere, remained free from the disease, a fact which seemed to prove that the infected farmhouse could not have communicated the disease to Lausen either through the ground water or through the air.

In order, however, to clinch the evidence that the Lausen water supply had been infected, it became desirable to show some source from which an infection, so unusual and remarkable, could have come, and precisely how it had happened. There had long been a belief that the Lausen well or spring was fed by and had a subterranean connection with a brook (the Furler brook) in the neighboring Fürler valley; and since this brook ran near the peasant's house and was known to have been freely polluted by the excreta of the typhoid fever patients, absolute proofs of the connection between the well of Lausen and the Furler brook could not fail to be highly suggestive and important. Fortunately such proofs were not far to seek. Some ten years before, observations had been made which had shown an intimate connection between the brook and the well. At that time, without any known reason, there had suddenly appeared near the brook in the Furler valley below the hamlet, a hole about eight feet deep and three feet in diameter, at the bottom of which a considerable quantity of clear water was flowing. As an experiment, the water of the little Furler brook was at that time turned into this hole, with the result that it had all flowed away underground and disappeared, and an hour or two later the public fountains of Lausen which, on account of the dry weather prevailing at the time, were barely running, had begun flowing abundantly. The water from them, which was at first turbid, later

became clear; and they had continued to flow freely until the Fürler brook was returned to its original bed and the hole had been filled up. But every year afterward, whenever the meadows below the site of the hole were irrigated or overflowed by the waters of the brook, the Lausen fountains soon began to flow more freely. In the epidemic year (1872) the meadows had been overflowed as usual from the middle to the end of July, which was the very time when the brook had been infected by the excrements of the typhoid patients. The water supply of Lausen had increased as usual, had been turbid at the beginning, and had had a disagreeable taste. And about three weeks after the beginning of the irrigation of the Fürler meadows, typhoid fever had broken out, suddenly and violently, in Lausen.

In order to make matters, if possible, more certain, the following experiments were made, but unfortunately not until the end of August when the water of the Lausen supply had again become clear. The hole which had appeared ten years earlier, and had afterward been filled up, was reopened, and the little brook was once more led into it; three hours later the Lausen fountains were yielding double their usual volume. A quantity of brine containing about eighteen hundred pounds of common salt was now poured into the brook as it entered the hole, whereupon there appeared very soon in the Lausen water, first a small, later a considerable, and finally a very strong, reaction for chlorine, while the total solids increased to an amount three times as great as before the brine was added. In another experiment, five thousand pounds of flour, finely ground, were likewise added to the brook as it disappeared in the hole; but this time there was no increase of the total solids, nor were any starch grains detected in the Lausen water.

It was naturally concluded from these experiments that while the water of the brook undoubtedly passed through to Lausen and carried with it salts in solution, it nevertheless underwent a filtration which forbade the passage of suspended matters as large as starch grains. Dr. Hagler, from whose report the foregoing facts are taken, was careful, however, to state that "it is not denied that small organized particles, such as typhoid fever germs, may nevertheless have been able to find a passage." As a matter of fact Dr. Hägler's minute account * does today give us some indication that

* *Typhus und Trinkwasser, Vierteljahrschrift fur öffentliche Gesundheitspflege*, v. VI. 154, also, *Sixth Report, Rivers Pollution Commission of 1868*, London, 1874.

such germs might easily have passed from the brook to Lausen, for the turbidity of which he repeatedly speaks is evidence of the passage of particles probably as small as, and possibly smaller than, the germs of typhoid fever.

Unfortunately this was before pure cultures of bacteria were known, and no experiments were made with suspended matters as small as bacteria. The conclusion was inevitable that although filtration had in this case sufficed to remove starch grains, it had been powerless to remove the germs of typhoid fever; and, accordingly, filtration as a safeguard against disease in drinking water fell for a time into disrepute.

An epidemic of typhoid fever in Caterham and Red Hill (England) traced to an infected ground water supply. — A number of epidemics of typhoid fever had been already traced with more or less certainty to polluted water supplies when, in 1879, there appeared a serious outbreak of this disease in the towns of Caterham and Red Hill in England. The duty of investigation of this case was assigned to Dr. Thorne-Thorne, and his report which appears in the *Report of the Medical Officer of the Local Government Board for 1879*, pp. 78–92, is a model of careful investigation and sound reasoning. Briefly summarized, it was as follows: The total number of cases affected during the epidemic proper was 352. The total number of deaths, 21. The disease was typical typhoid fever, the patients exhibiting the characteristic rose-spots and diarrhea and some of them suffering from severe pulmonary and intestinal complications, the latter including perforation of the bowels, which in four cases, was the immediate cause of death. The first person attacked sickened on January 19, 1879; a second, on the 20th; two more on the 23d; three on the 24th, and thenceforward up to February 2, to which date information was at first limited, fresh attacks in fresh houses occurred day by day.

Caterham lies in the rural sanitary district of Godstone, and had a population of about 5,800. It included at this time a portion called Lower Caterham, near the head of the Caterham valley, a valley bounded by chalk hills. The houses in this part consisted mainly of superior villa residences. The other or upper part lies at a higher altitude. Here, also, are a number of villas, one of the asylums belonging to the Metropolitan District Asylums Board, and certain barracks.

The cases of typhoid fever referred to, and which had occurred

in the fortnight ending February 2, were spread over a very wide area, some in Upper and some in Lower Caterham, extending to the extreme outskirts of both places. The families attacked belonged to no special class, both rich and poor having suffered. It was apparent that the disease could not have been conveyed by means of any general system of sewers for the majority of the houses drained into separate cesspools. There was also no possibility that there had been any common cause of infection in connection with the prevailing means of excrement disposal, because there was nothing in common with regard to such disposal. The possibility of infection by means of milk supply was next inquired into, but disproved. It was also evident that personal infection could not in any way have led to the outbreak. Finally, it was stated that for some years past the locality had been remarkably free from the disease, and only one isolated case occurred during the twelve months preceding the outbreak, and this case was believed to have been imported.

Caterham was supplied with water by the Caterham Waterworks Company, and of the forty-seven persons attacked during the fortnight in question, forty-five resided in houses supplied with this water. Suspicion was thus directed to the water supply, and was confirmed when it was ascertained that the two remaining patients, though living on premises having private wells, had been in the habit of spending the day at houses supplied with the company's water, and had admittedly used this water.

It further appeared that in the Caterham Asylum, having nearly two thousand patients, no typhoid fever had appeared, and that there had been a similar absence of the disease among the five hundred men in the barracks. Both these establishments derived their entire water from a well sunk 462 feet into the chalk.

In the meantime, information arrived that typhoid fever was also epidemic in Red Hill, a neighboring community. Red Hill had an estimated population of 9,500, and included two or more villages, besides an asylum for idiots. It was about eight miles distant from Caterham, lay on a different geological formation, and was well sewered. Nevertheless, in regard to typhoid fever, the two places were remarkably similar. In both, the epidemic began at about the same time. The first two cases in Red Hill occurred on January 20; three more on the 21st; five more on the 22d; twelve on the 23d, and at the end of the first fortnight, namely,

by February 2, the total number of houses affected was 96, and the number of patients had reached 132. There was nothing which threw suspicion upon the sewers. The community had been totally free from the disease for at least eighteen months, and there was no reason to suspect the milk supply. The water supply, on the other hand, was derived for the most part from the waterworks of the Caterham Waterworks Company, and a sanitary official, Mr. Jacob, independently of Dr. Thorne and the local officer in Caterham, had arrived at the conclusion that the Caterham water was in all probability the vehicle of the disease. Of the ninety-six houses affected during the first fortnight of the epidemic at Red Hill, ninety-one actually drew their water from the Caterham Company's mains, and the histories obtained with reference to the attacks in the remaining five cases were such as to confirm the impression that the Caterham Company's water had been the immediate cause of the epidemic. For example, at one of these houses where ultimately three persons were attacked, the supply, as was hitherto believed, had been exclusively derived from a rain water tank, but it was now ascertained that the Caterham Company's water was in addition procured surreptitiously; that at another house, for which there was apparently no water supply, the company's water was procured from a neighbor's; and with regard to the remainder, the patients infected were not only persons who were employed where the company's water was in use, but several of them had partaken of the water at their meals.

Certain localities in Red Hill, namely, Meadvale, having about 160 houses, and in Red Hill itself a group of 30 houses supplied with wells, were practically exempt from typhoid fever. Still more striking was the case in Reigate, a town which forms the western ward of the borough of which Red Hill is the eastern ward. Reigate had a population of about 8,500, provided, however, with a different water supply; and this region escaped entirely, only two cases, undoubtedly imported from Red Hill, having occurred there.

All the facts ascertained in connection with the course of the epidemic up to February 2 afforded very strong presumption that it had been caused by the use of the Caterham Company's water. Further developments made this view almost certain.

The Waterworks Company derived its supply from two deep wells, situated about 30 feet apart, and about 490 feet deep. Both were several feet in diameter. Moreover, they were connected by

three adits in the chalk. From the wells the water was pumped to reservoirs, in which it was submitted to Clark's softening process. The reservoirs freely communicated and from them the supply was delivered by gravitation. During the preceding twelve months a third well had been made, 90 feet away from the others and of similar depth. From 1861, and until the construction of the third boring, the water supplied by the company was held in high repute; but since that time, and prior to the epidemic, complaints had been made with regard to the water. These were due to an unavoidable turbidity and to interruptions in the process of softening. Apart from this turbidity and carbonate hardness, there was no reason to believe that the water was objectionable; and considering the deep sources of the supply, it was by no means apparent how the water could have been the means of producing an extensive epidemic of typhoid fever. Dr. Thorne inquired carefully into the possibility of contamination of the supply *en route*, but with negative results. He next sought to discover whether any contamination had taken place in the reservoirs or in the mains. But these sources also were satisfactorily excluded. Many other points relating to the method of distribution of the water were inquired into, but none led to any explanation of the circumstances of the epidemic.

It was next suggested that cesspool drainage or soakage of surface filth might have existed around the company's wells. Certain cesspools were found in the vicinity, but after careful examination were excluded as probable sources of contamination.

In the meantime facts were brought to light which led to an extension of the inquiry in another direction. It appeared that during the latter part of 1878 and the beginning of 1879, the company had constructed an adit from one of their old wells up to the new boring, which was then being sunk. This adit was in the chalk at a depth of 445 feet. It was 6 feet by 4 feet in section and 90 feet long. A number of men were employed in the work, some of them being in the wells below, others on the surface. It was ascertained that one of the men who left work some time in January was reputed to have been ill, though no inquiries had been made concerning him since he left the works. This man was sought out, and eventually the following facts were obtained:

"J. K., aged thirty-two years, resided in Caterham, and was employed by the company as a laborer from October 25, 1878. The

work assigned to him was that of 'loading-man,' he being employed in the adit below in attaching to a rope let down from above the buckets by which the excavated chalk was raised to the surface, and in again receiving those buckets when lowered full of bricks and cement required for the work in progress. From December 14 to December 29, J. K. was absent. When he returned he was in perfect health, but in about a week, that is, about January 5, 1879, he felt himself ailing. His symptoms, which, according to his statement, steadily increased, were at first loss of appetite, recurring attacks of shivering alternating with a feeling of heat, great pains in the limbs which he attributed to rheumatism, but which, instead of being confined to any of the joints, were described both by himself and by his wife as an 'aching all over,' and diarrhœa. As the symptoms became aggravated, he was so exhausted during his work and became so 'giddified' that he was more than once drawn to the surface, and immediately on his return home he was compelled to go to bed. More than once his wife noticed that he was 'light-headed' in his sleep. All this while the diarrhœa continued, the man making a great effort to remain at his work, because, as explained, he had had no employment between the 14th and the 29th of the previous month.

"With reference to this man's diarrhœa, it is necessary to make the following explanation: Both from his own statement, and from that of others, it appears that all the men who worked in the adit were expected to make such preparation before descending the well that no occasion should exist for relieving themselves below; but should such necessity ever arise, and should there be at such a time any difficulty or delay in their being drawn to the surface, the buckets which were regularly being raised to the surface were to be used for that purpose. J. K. states that he strictly complied with these regulations before descending, but that, notwithstanding all his efforts, the purging under which he was laboring was such that he was compelled to evacuate whilst in the adit 'at least two or three times' during each shift, the shifts lasting apparently from eight to twelve hours each, according to circumstances. Indeed, as time went on, the man's diarrhœa must have been considerable, for besides the attacks which came on whilst in the adit, he almost invariably suffered from it before descending, immediately after ascending, and also at his own house. So matters continued until January 20. when work was again suspended for two days on

account of a rise in the water level. But during the night of the 21st he was so much worse that he was unable to rise next morning. According to his wife's statement, he found he could not stand when he got up, and returning to his bed, suffered from 'shivering down the back, aching, and exhaustion'; and later on severe abdominal pain came on which compelled him to lie with his knees drawn up; he was also 'burning hot.' This pain was looked upon as 'cramp,' and was alleviated by linseed-meal poultices, which were applied by his wife. The more severe symptoms, including the diarrhœa, having subsided, he was two days afterward able to get up for a while, and from this time convalescence appears to have set in. No medical advice was sought, mainly, as he explained to me, owing to his straitened circumstances. When I saw him, on February the 8th, he had the aspect of a man who had recently suffered from some acute disease; he was still very weak, and it was obvious that he had greatly lost flesh."

Dr. Thorne and Mr. Jacob, with extreme care, searched further into the history of this case, with the following result, in Dr. Thorne's words:

"I have now no hesitation in taking it as a fact, that a man ill of enteric [typhoid] fever from January 5 to the end of the month was occupied during the first fortnight of that period at work in the well of the Caterham Waterworks Company. The fact, it will be observed, is not inferred from any consequences of it, but simply from what was seen and heard of the particular individual.

"But now let us see what those consequences would have been. If this man's stools could by any means have found their way into the water of the well in which he had been working, and being enteric fever stools could thus have led to the development of the poison of that disease in the well, the effect on the water consumers ought to have been noticed within from about ten to fifteen days after the date when the diarrhœa first came on. And this, in effect, is precisely what did take place, the epidemic having commenced on January 19 and 20 in Caterham and Red Hill, respectively. This remarkable concurrence of dates led to a more detailed inquiry as to the course of the man's diarrhœa whilst working in the adit. He admitted that the purging was very copious, in short, that it 'ran from' him; indeed, when at home, he was, because of the suddenness of its onset, unable to resort to the closet. He further admitted that, owing to his frequent use of the bucket whilst at

work, complaints were made by his fellow-workmen on the surface; but he stoutly denied that he had ever been so pressed by necessity, or so influenced by those complaints, as to relieve himself in the adit without waiting for a bucket. But even accepting his denial, there were undoubted means by which his evacuations could have found their way into the water. According to his statement, the bucket was used as a closet when it was empty, when half full, and when full; he added, however, that when it was full he first took some of the chalk out and subsequently replaced it. During an earlier stage of my inquiry I had occasion to descend one of these wells, and I noticed that any article let down by a rope, by its oscillations to and fro, came into constant and somewhat violent contact with the walls of the wells, and on inquiry of J. K. whether the same did not take place with the bucket, he admitted not only that this was so, but that some of its contents frequently fell over a stage into the water below. On further inquiry, he added that some portions of his evacuations probably did so also. And he further stated that the looseness of his bowels was such that the bucket itself must almost of necessity have been stained with them. This bucket, which was merely emptied out above, then received, as already explained, materials which were used in the construction of the works below. Here, then, were the stools of an enteric fever patient, from about January 5 onwards, getting into the Caterham Company's water and distributed with that water to the district served by the company. There can, I think, be no doubt that we have in the man J. K. the cause of the disease which followed."

The total number of cases was 352, and the total number of deaths, 21, to the end of February. After that time only a few scattered cases occurred. Most of the cases were of an exceptionally mild character, and the majority attacked were children. Among adults, women were more frequently attacked than men.

An epidemic of typhoid fever in Plymouth (Pennsylvania) traced to a polluted surface water supply. — One of the most instructive epidemics in the annals of sanitary science is the epidemic of typhoid fever which sprang from a polluted water supply in Plymouth, Pa., in the spring of 1885. Plymouth at that time was a mining town of about eight thousand inhabitants. It had grown up rapidly, and was not in good sanitary condition; but it was provided with an apparently excellent, though limited, public water supply derived from a mountain stream, traversing

an almost uninhabited watershed. There were, in fact, on the watershed only two houses so placed as to be able to contaminate the supply. It would appear from the excellent report of Dr. L. H. Taylor,* of Wilkesbarre, from which the present account is drawn, that the inhabitants of one or both of these had for some time, perhaps for years, been polluting the public supply of Plymouth with ordinary fecal matters; but no harm was observed or even suspected until April, 1885, when, as was afterward discovered, the specific infection of typhoid fever was superadded to ordinary fecal pollution. Thereupon, out of a population of about 8,000 persons, 1,104 contracted typhoid fever, and 114 died. The story is as follows:

"The first case belonging to this epidemic occurred on April 9, and from this time on the disease spread rapidly. During the week beginning April 12, from fifty to one hundred new cases appeared daily, and on one day it is said two hundred new cases were reported. . . . Various theories were put forth, some declaring it [the epidemic] to be due to the filth of the town; some that it was due to drinking polluted well water; others, polluted river water; and still others that it was due to a peculiar condition of nature, by no means explainable.

"Among the various theories advanced, one of the first was that it was due to the accumulated filth of the town, which, being acted upon by the warm rays of the April sun, had suddenly become noxious, and the emanations, therefore, had caused the disease. This especially suited the 'typho-malarial' theorists. But although Plymouth was not an especially clean town, it was not, on the other hand, more filthy than other neighboring towns where the disease did not prevail, nor was it at this particular time in worse condition than in preceding years. . . .

"All classes of people were attacked, the clean as well as the filthy, and all parts of the town affected, the highlands as well as the valley . . . and thoughtful minds naturally turned to the water supply as furnishing the true cause of the invasion."

In addition to certain wells and springs the inhabitants had access to one or both of two public water supplies. A small portion of the town received regularly water from the Susquehanna River, pumped by the Delaware and Hudson Coal Company, and those

*_First Annual Report, State Board of Health and Vital Statistics of Pennsylvania_ Harrisburg, Pa., 1886, pp. 176–195.

who used this water exclusively did not suffer from the disease. The greater portion, however, was supplied by the Plymouth

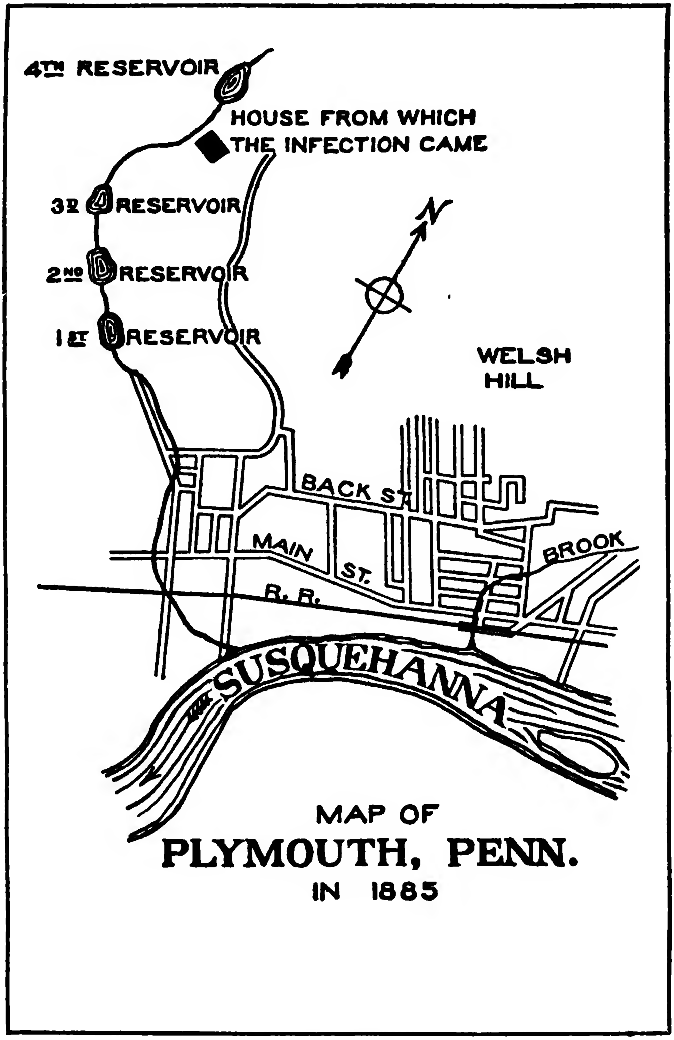


FIGURE 4

Water Company, which in 1876 began supplying the town "with water of remarkable purity, from a neighboring mountain stream which had its source in a beautiful sand spring some miles away."

On the stream had been built, successively, four storage reservoirs: No. 1, the first, the lowest, and that serving as the distributing reservoir (see diagram), having a capacity of 300,000 gallons; No. 2, next above, a capacity of 1,700,000 gallons; No. 3, still higher, of 3,000,000 gallons; and finally, No. 4, highest of all, of 5,000,000 gallons. In spite of this storage capacity, however, the supply was at times insufficient, and was then supplemented by direct pumping from the Susquehanna River, a stream polluted, and at times infected, by the sewage of Wilkesbarre, a city of 30,000 inhabitants, lying on the same river only three miles above. "Water from the river was first pumped . . . in 1878, and occasionally in succeeding years, *e.g.*, in 1881, 91 days; in 1882–1883, . . . 65 days; 1883–1884, 124 days; 1884 [additional], 118 days. This water, though objectionable, . . . has never been followed by any [reported] epidemic of typhoid fever."

In the spring of 1885 resort was again had to the river, which was used just before the epidemic appeared, viz. from March 20 to 26, 1885. Dr. Taylor was therefore obliged to consider very carefully the possibility that the source of the epidemic lay in the river water. He was able, nevertheless, by various independent lines of evidence, to show conclusively that the great epidemic, which began with a single case on April 9, and by the end of another week had risen to alarming proportions, could not possibly be attributed to the use of the sewage-polluted river water. It was easy to show that the milk supply and the well-water and spring-water supplies could not furnish adequate explanation of the epidemic, so that there remained only the mountain supply of water to be investigated.

"There remains but one possible cause for this most serious and deplorable outbreak, and that is contamination of the water supplying the company's reservoirs. A glance at the accompanying map will show the location of this stream and of the several reservoirs. Above the starting point of the water pipes there is but one house situated upon the banks of this stream, and one upon the banks of the fourth reservoir.

"In the house between the third and fourth reservoirs, situated almost immediately upon the stream, there lives a man who but recently has recovered from the effects of a severe attack of typhoid fever. This patient went to Philadelphia, December 24, 1884, and while there, he thinks, contracted the disease. Whether he did

thus contract the disease in Philadelphia may, we think, admit of question. But it is nevertheless true that he returned to his home, January 2, 1885, and for many weeks was seriously ill with genuine typhoid fever. Early in March he was convalescent and was out of bed. A relapse occurred about the middle of March, and he was very sick on the 16th. On March 16 and 17 he had hemorrhages of the bowels of so severe a type, that on March 18 his life was despaired of, even by his physician.

"He, however, rallied, was quite ill for some time, but was convalescent in April, so that his physician discontinued his visits after April 12.

"During the course of his illness, his dejecta passed at night, without any attempt at disinfection, were thrown out upon the snow and frozen ground toward and within a few feet of the edge of the high bank which slopes precipitously down to the stream supplying the town with water.

"The nurse in charge states explicitly that in emptying the chambers at night she did not stand on the porch to throw out the contents, but stepped down some distance and threw them into the creek. If she stepped but a few feet away from the porch, she would empty the excreta within twenty-five or thirty feet of the edge of the stream.

"The dejecta passed during the day were emptied into a privy a little farther back, the contents of which lie almost upon the surface of the ground, and at the first thaw or rain they too would pass down the sloping bank and into the stream. These dejecta were thrown out from time to time until the accumulation no doubt equalled the daily passages from many such patients. They remained innoxious upon the snow and frozen ground until some time between March 25 and April 1, when they were washed into the stream and thence into the third reservoir.

"The house in question does not stand in a ravine nor in a protected spot, but in an open clearing, with land sloping toward the south, which clearing would naturally feel the effects of the sun's rays and part with its snow and accumulated filth sooner than the more protected regions which also drain into the stream, so without cavil the first water from the effects of the thaw to enter the third reservoir would be from the melted snow in the immediate vicinity of this house.

"The maximum temperature . . . was on March 26, 46.5° F.;

March 27, 56°; March 28, 43°; March 29, 37°, increasing rapidly until April 4, when a temperature of 70° F. was reached.

"March 26, with a maximum temperature of 46.5° F., is the first day on which any considerable thaw could occur. Upon the evening of this day, the superintendent of the water company visited the reservoirs to ascertain whether it would be allowable to discontinue the pumping of river water. He found the first and second reservoirs almost entirely empty, while the third was filling rapidly, the short pipe which allows the water to discharge from the bottom of the third into the stream leading to the second reservoir being tightly frozen.

"He caused a fire to be built to melt the ice in this pipe, and then stopped the river pumps. The honest act of an honest man, and simply in the discharge of his duty and with kindliest intent. But of what a catastrophe was he the unconscious usher and hastener! The water, with its accumulated typhoid fever poison, was discharged from the bottom of the third reservoir, ran down to the second, on to the first, and was thence distributed to the town, in all probability between the 28th of March and the 4th or 5th of April.

"In considering the possibility of one patient poisoning more than a thousand in Plymouth, we must bear in mind all the attending circumstances:

"1. The accumulation of weeks — which equalled the dejecta from many ordinary patients, and which lay for a time dormant upon the snow and frozen ground.

"2. The nearness to the stream. The house is so situated that all of the excreta were thrown within a few yards of its banks, and the conformation of the ground is such that its surface water could not possibly drain in any other direction.

"3. The unusually warm weather — which caused a sudden thaw and poured the surface water into the empty reservoir.

"4. The concentration of the poison in a small amount of water.

"5. The short distance to the town; and finally, the possible previous preparation of the soil for the reception of this seed, which sprang at once into vigorous growth and ripened for an abundant harvest of death.

"It would seem that the mere statement of facts, as found in the few preceding pages, is amply sufficient to explain the cause of this remarkable epidemic, and we need have no hesitation in

declaring the pollution of the mountain stream, which supplies the reservoirs of the water company of Plymouth, to be the sole cause of the remarkable outbreak of typhoid fever in this borough.

"During the period of pumping from the Susquehanna, the water in that river was lower than it had been at any time for years, and the surface was frozen tight. The city of Wilkesbarre, containing thirty thousand inhabitants, delivers its sewage directly into the Susquehanna, the mouth of the lower sewer emptying only two miles above the Plymouth Pumping Station, while the current is very rapid between the two towns. The water is further contaminated by refuse water from five or six lines as well as by the garbage from the abattoirs at Wilkesbarre. Notwithstanding this unusually filthy condition of the Susquehanna River, it is beyond question entirely innocent of causing the epidemic. . . ."

Dr. Taylor's conclusions were confirmed in all essential particulars by other students of the epidemic, among whom may be mentioned Drs. Shakespeare and French of Philadelphia; Briggs of Buffalo; and Biggs, Taylor, Edson, and others, of New York. The first to suggest publicly the pollution of the mountain supply as the probable cause of the epidemic was Dr. R. Davis (in a Wilkesbarre newspaper published on April 29).

We may readily agree with Dr. Taylor in his conclusions:

"It is safe to say that this was one of the most remarkable epidemics in the history of typhoid fever, and it teaches us some important lessons at fearful cost. One is, that in any case of typhoid fever, no matter how mild, nor how far removed from the haunts of men, the greatest possible care should be exercised in thoroughly disinfecting the poisonous stools. The origin of all this sorrow and desolation occurred miles away, on the mountain side, far removed from the populous town, and in a solitary house situated upon the bank of a swift-running stream. The attending physician did not know that this stream supplied the reservoirs with drinking water. Here, if any place, it might seem excusable to take less than ordinary precautions; but the sequel shows that in every case the most rigid attention to detail in destroying these poisonous germs should be enjoined upon nurses and others in charge of typhoid fever patients, while the history of this epidemic will but add another to the list of such histories which should

serve to impress medical men, at least, with the great necessity for perfect cleanliness — a lesson which mankind at large is slow to learn.

"Another lesson taught by this history comes more nearly home to us all. The water-companies throughout our land should be taught that they must furnish us the water for which we pay, from the very best source which the country affords. Not only should they avoid the use of river water contaminated by sewage, but they should be compelled to remove from the banks of their streams and reservoirs not only all probable, but all possible sources of pollution."

Another lesson which this epidemic teaches is that cold, even at or below freezing temperatures, does not kill typhoid bacilli encased and protected in human feces. The living typhoid organisms remained viable in their fecal environment at or near freezing temperatures for over three months. When warmer weather came, and melting snows and rains began to make their way into the reservoir, the infected fecal material on the ground was washed into the water supply. Since typhoid bacilli do not survive in water for long periods of time, this epidemic also demonstrates that where water-borne typhoid occurs, the organisms ingested are of recent intestinal origin and are in all probability the organisms originally discharged by the patient rather than their descendants. The epidemic indicates further that in water-borne typhoid, the concentration of typhoid bacilli in drinking water required to produce disease does not have to be large.

Typhoid fever in Lowell, Lawrence, and other cities on the Merrimac River. — In the valley of the Merrimac River, which is a large, swift stream draining a considerable portion of southern New Hampshire and northern Massachusetts, are situated a number of cities and towns of which the history in respect to typhoid fever is interesting and instructive. Situated in the same valley, under closely similar climatic conditions, they are also, for the most part, manufacturing towns or cities, and have populations especially favorable for purposes of sanitary comparison. Lowell, Lawrence, and Manchester are devoted chiefly to textile industries, and nearly the same might be said of Nashua and Concord, while Haverhill is what is called a "shoe" town, and Newburyport, while possessing some textile industries, is more diversified in this respect.

In connection with his duties as biologist to the State Board of Health in Massachusetts, and especially with his work at the Lawrence Experiment Station of that Board, Professor Sedgwick was already somewhat familiar with the sanitary history of the cities and towns situated in the Merrimac valley, when, in December, 1890, a serious epidemic of typhoid fever having appeared in the city of Lowell, lying only nine miles above Lawrence, he was instructed by the Board to make a thorough investigation. At almost the same time he was also invited by the Water Commissioners of Lowell to conduct a similar inquiry on their behalf.

The death rates from typhoid fever in the principal cities of the Merrimac before and after the outbreak of the great epidemic of 1890–1891 are shown in the following table:

TABLE 10

DEATH RATES FROM TYPHOID FEVER, BY PERIODS OF TWELVE MONTHS, IN THE PRINCIPAL CITIES ON THE MERRIMAC RIVER, FOR THE FIVE YEARS, APRIL 1, 1888, TO MARCH 31, 1893

(Deaths per 100,000 Inhabitants. Population from United States Census of 1890)

	FROM APR., 1888, TO MAR., 1889	FROM APR., 1889, TO MAR., 1890	FROM APR., 1890, TO MAR., 1891	FROM APR., 1891, TO MAR., 1892	FROM APR., 1892, TO MAR., 1893	AVERAGE APR., 1888, TO MAR., 1893
Concord, N.H.	70.5	29.5	53.0	29.4	11.8	38.8
Manchester, N.H.	29.9	41.8	43.6	11.5	20.7	29.5
Nashua, N.H.	68.9	42.5	5.3	89.8	31.8	47.7
Lowell, Mass.	86.3	83.9	195.4	81.7	85.6	106.6 [1]
Lawrence, Mass.	125.2	118.1	187.0	91.6	114.1	127.2 [1]
Haverhill, Mass.	22.8	30.3	33.9	30.2	64.0	46.3
Newburyport, Mass.	14.4	28.8	57.6	28.8	50.4	36.0

[1] Excluding 1890–1891 (the period of the great epidemic), the average for the other four years is 84.4 for Lowell, and for Lawrence, 112.25.

A very brief consideration of the facts laid down in this table reveals certain striking phenomena. In the first place it is evident that none of these cities was free from typhoid fever, at least for any considerable length of time. In the second place the average amount of typhoid fever in all the cities excepting Lowell and Lawrence was very much the same. In these cities, there was a marked excess of typhoid fever, and in the year of the great epidemic (1890–1891) this excess is especially notable. Those who desire to follow the facts of this epidemic in detail are referred to

the original reports.* The main points, however, will be touched upon here.

As has already been stated, these cities were closely similar in climate and industrial pursuits, and the same thing was true in every other important respect excepting one, namely, their water supply, which in the cases of Lowell and Lawrence only, had been derived directly from the Merrimac River, a sewage-polluted stream, without any attempt whatever at purification. The water supplies of Concord, Nashua, and Haverhill, and during most of the time of Newburyport, on the other hand, were derived from other sources, as a rule entirely unobjectionable, and in some cases, as for example that of Nashua, remarkably pure.

When in the autumn of 1890 the great epidemic of typhoid fever broke out in Lowell, one even more severe soon after appeared in Lawrence. The former was traced to an unusual infection of the Merrimac River by cases of typhoid fever in a suburb of Lowell, through a little feeder of the river known as Stony Brook, which entered it only three miles above the intake of the waterworks. That in Lawrence was plainly due to the same cause, to which was added the pollution and infection of the river by the sewage of Lowell (at that time a city of eighty-five thousand inhabitants), the sewers of which emptied into the river only nine miles above the intake of the Lawrence waterworks. There were altogether probably upward of fifteen hundred cases of the disease in the two cities as a result of this infection of the public water supplies.

A number of interesting facts were developed as the result of careful studies made of this epidemic by Mr. Hiram F. Mills, Mr. George V. McLauthlin, and Professor Sedgwick. It was discovered by Mr. Mills, that Lowell and Lawrence had long suffered annually from two autumn increments of typhoid fever instead of one, as was customary in most places, and that the first was contemporaneous with that in other cities and towns of the state, while the second arrived considerably later. The latter was evidently due to the fact that the water supplies of the two cities had become infected as a result of the usual autumn increment of the disease in the cities and towns on the river above, so that the second increment was a crop of which the first was the seed.

*On recent epidemics of typhoid fever in the cities of Lowell and Lawrence due to infected water supply, with observations on typhoid fever in other cities and towns of the Merrimac valley, especially Newburyport. *Twenty-fourth Report* [for 1892] *State Board of Health of Massachusetts*, Boston, 1893, pp. 667–704.

The problem of typhoid fever in these cities was much complicated by the prevailing custom of distributing in the numerous mills and factories water so placed as to be accessible and used for drinking purposes, which was derived directly from the little branches of the unpurified river (called *canals*) which were used for power and washing purposes by the mills, and which were in some cases polluted within the city itself by excreta from other mills, the public hospital, privies, etc.

An epidemic of Asiatic cholera in Hamburg, Germany, traced to an infected public water supply. — The great epidemic of Asiatic cholera which occurred in Hamburg in 1892 was traced to an infection of the public water supply, and was probably due to the excrement of certain Russian emigrants detained for a while in crowded barracks on the banks of the Elbe River while *en route* to America. Among these emigrants, many of whom came from areas in Russia where cholera had been raging, were doubtless some mild and missed cases of cholera, as well as others who were still convalescent carriers. The dejecta of these people were disposed of in the Elbe River as was the sewage of the city of Hamburg. The water supply of Hamburg at that time was derived directly from the Elbe, and pumped, without purification of any kind, into the water mains for the immediate use of the citizens. A neighboring suburb (Wandsbeck) and the city of Altona which forms virtually a part of Hamburg, remained almost entirely free from the disease. The former, population 20,000, had an excellent water supply not drawn from the river; the latter, population 143,000, drew its water supply from the river at a point below the outfall sewer of the city of Hamburg, and this water supply, therefore, contained more sewage than did the Hamburg water, but with this difference: — the Altona water supply was purified by slow sand filtration before it was delivered to the consumers. The Hamburg water supply was untreated. After the epidemic, Hamburg also introduced excellent filters with most satisfactory results.

This epidemic is one of the most interesting in the history of sanitary science. It demonstrated that disease follows the lines of travel, for several cases of cholera among emigrants embarking at Hamburg arrived on board ship in New York and caused great consternation in America. A few cases actually did find their way into this country. The price of safety against the importation of disease from abroad is eternal vigilance.

Another lesson which this epidemic taught was that the slow sand filter is an efficient method of purifying even a heavily polluted and infected water supply. The epidemic began on August 17, 1892, and lasted until October 23, 1892, — a little over two months. During that time, Hamburg, with a population of 640,000, had 17,000 cases of cholera and 8,605 deaths from this disease. The death rate per 100,000 population was 1,342. Hamburg drank unpurified river water which was polluted with sewage. Altona, which was essentially a part of Hamburg, and which also obtained its water supply from the polluted Elbe River, purified the water by slow sand filtration. It had a population of 143,000, but there were comparatively few cases during this epidemic. Nevertheless there were 328 deaths, equivalent to a death rate of 234 per 100,000 population. Since many residents of Altona worked in Hamburg, it is not surprising that some of them contracted cholera. The prevalence of the disease in Altona, however, was limited in comparison with Hamburg.

This epidemic also gave conclusive evidence once more that water is an important vehicle of intestinal disease. Not only did Altona suffer much less than Hamburg because it purified its water supply, even though the source was the same and more heavily polluted, but the suburb of Wandsbeck, which obtained its water supply from a totally different source, and which had a very good water supply, also escaped the serious consequences of this epidemic. Wandsbeck which had a population of 20,000, experienced 43 deaths during the epidemic, and had a cholera death rate of 215 per 100,000 population. Furthermore, since the boundary line between Hamburg and Altona in one portion of the city ran down the middle of a street, and the houses on one side were supplied with filtered Altona water while those on the other side were supplied with unfiltered Hamburg water, it was interesting to find that the people receiving Altona water escaped infection, while those obtaining Hamburg water experienced the epidemic.

This epidemic was studied by the great German bacteriologist, Dr. Robert Koch. He was able to isolate the vibrio of cholera from the polluted Elbe River water, thus concluding the chain of evidence that the epidemic was water-borne, and that the drinking water contained the organism regarded as the causative agent of cholera.

Dysentery and diarrhea. — In the case of dysentery and diarrhea, there is also no doubt that drinking water may be and often is their ready vehicle. In almost all cases in which a pure water supply has been substituted for one impure, a marked diminution can be shown in the deaths attributed to these disorders.

Previous to the improvement of the water supply of Burlington, Vt., in 1894, dysentery, and especially diarrhea, were relatively prominent among the assigned causes of mortality; but since that time they have been insignificant. The case of Burlington, in respect to diarrhea, is peculiarly instructive. In the early sanitary history of that city, when the water supply was drawn without purification from a point on the shore of Lake Champlain, relatively near the place where the principal sewer emptied into the same lake, typhoid fever and diarrhea both prevailed to an alarming degree. When, later (in 1885), the main sewer outfall was removed to a greater distance, typhoid fever diminished, but diarrhea remained very prevalent. When, still later, in 1894, the sewage outfall and the water intake were still further separated — the water intake having been carried out some three miles into "the broad lake" — endemic diarrhea also disappeared.

The Chicago Drainage Canal case. — It is impossible to conclude this historical review of some of the most famous epidemics of water-borne intestinal disease without saying a word about the famous case of the Chicago Drainage Canal. Chicago, the great metropolis of the middle west, with a population of 3,000,000, is located on the southwestern shores of Lake Michigan. For many years, even as today, it obtained its drinking water from the lake. Unfortunately, it also discharged its sewage into the same body of water. As the city grew in size the area of Lake Michigan polluted with Chicago's sewage became greater and greater, infecting the drinking water, and causing typhoid fever to be endemic in the city. In order to minimize the evil effects of this method of sewage disposal Chicago pushed its water intake further out into the lake where the water was purer. Soon, however, even this water became polluted with the ever-increasing volume of sewage discharged, and it was obvious that something drastic had to be done. Either Chicago had to purify its water artificially, or else exclude its vast daily river of sewage from its drinking water. It chose the latter course.

In so doing, it really performed a miracle, altering the natural flow of a stream — the Chicago River — and causing it to discharge into the Mississippi River, 357 miles away, instead of into Lake Michigan at its very door. In order to do that, however, Chicago built the famous Drainage Canal into which it poured its sewage, and then proceeded to take water from Lake Michigan mostly by gravity in amounts eventually as high as 75,000 gallons per second, in order to dilute it, and send it on its way to the Mississippi River. This plan relieved Chicago of a serious public health problem temporarily, but it created others, the solution of which has not been accomplished even after a lapse of more than 30 years.

In the first place, the construction of the Chicago Drainage Canal resulted in a famous sanitary law case in which the state of Missouri tried to obtain an injunction to restrain Chicago from dumping its sewage into the Mississippi River. The case was tried before the U.S. Supreme Court, and since the evidence submitted did not prove that Chicago was creating a nuisance or menace to health to the people of St. Louis and Missouri, the Court refused to grant the injunction requested.

A second problem created by the Chicago Drainage Canal arose from the diversion of enormous quantities of water from Lake Michigan required to dilute the sewage of Chicago, and to send it on its way to the Mississippi River without creating a nuisance. This resulted in charges by other Great Lakes cities that the level of the water in the lakes was being lowered and that shipping was being endangered. The matter became a subject of international concern since Canadian cities on the Great Lakes were likewise affected. Finally the U.S. Supreme Court heard further evidence through a Special Master and decided that Chicago was to continue to build adequate sewage treatment facilities in order that the need for withdrawing large quantities of water from Lake Michigan might cease. It specified furthermore that permission to withdraw large quantities of water from Lake Michigan would be limited to the next few years, and that the amount withdrawn should be gradually diminished with the passage of time.

This illustration is an example of the absolute dependence of the modern municipality on a pure water supply and the extent to which a city will go to satisfy that primary essential of life. Chicago built the Drainage Canal; it altered the natural course of a river;

it built extensive sewage treatment plants, including one of the largest activated sludge plants in the world; and it is chlorinating over 600,000,000 gallons of Lake Michigan water daily, in order to deliver a safe water supply to its people. As a result, the typhoid fever incidence and mortality in Chicago today compare favorably with similar rates that prevail in any part of the world.

The Mills-Reincke Phenomenon and Hazen's Theorem. — The epidemic of typhoid in Lawrence, Mass., in 1890–1891, resulted in the introduction of slow sand filtration for the purification of the Merrimac River water. The cholera epidemic at Hamburg, Germany, in 1892, and the demonstration of the effectiveness of slow sand filters as purifying agencies at Altona, resulted in the introduction of similar filters for the purification of the Hamburg water supply. Curiously enough, and unknown to each other, two scientifically minded people, one on each side of the Atlantic, were studying simultaneously, the effects of water purification by slow sand filtration on the mortality rates in two large cities. Dr. J. J. Reincke, Health Officer of Hamburg, noted, that following the purification of the water supply for Hamburg, not only did the death rate from typhoid fever and other intestinal diseases diminish, but there was a simultaneous and altogether unexplained reduction in the mortality rates from non-intestinal diseases. Mr. Hiram F. Mills, studying the same problem simultaneously in Lawrence, Mass., observed the same phenomenon. Professor Sedgwick and one of his pupils, Mr. J. Scott MacNutt, studied this question for other cities several years later, and observing a similar state of affairs, called it the Mills-Reincke Phenomenon. Allen Hazen, also a pupil of Professor Sedgwick, studying the same problem, came to the conclusion that for every death from typhoid fever saved by water purification, there were 3 or 4 deaths saved from non-intestinal causes. This observation, Professor Sedgwick called Hazen's Theorem.

In the light of subsequent investigations of this subject, considerable doubt has been thrown on the validity of the Mills-Reincke Phenomenon and Hazen's Theorem. There is no doubt, however, that a pure water supply diminishes the prevalence of intestinal diseases like typhoid fever, dysentery, cholera, and diarrhea. There is also no doubt that the absence of intestinal disease and its serious, debilitating effects, maintains the vital resistance of the individual and thus prevents or helps to prevent

other diseases like tuberculosis, pneumonia, etc. Thus the purification of a water supply has a direct effect on the prevalence of intestinal disease, and an indirect effect, difficult to measure, on many of the non-intestinal diseases. The recent serious drought in the United States which affected certain areas in the middle west, did not result in a serious increase in the prevalence of typhoid fever, because sanitarians protected the people against this disease by chlorination, but it did result in the use of polluted water supplies, which in the opinion of students of the subject, gave rise to minor debilitating intestinal ailments. The lesson of the importance of safe and pure water has been bought at a tremendous cost in human life. It is doubtful whether man will ever forget the significance of this sanitary triumph. While the nineteenth and twentieth centuries are replete with remarkable scientific achievements, there is probably none that surpasses in magic and importance the discovery that filtration of water through several feet of sand will render it free of the organisms capable of causing widespread misery, sickness, and death.

Recent water-borne epidemics of disease. — While the great epidemics of water-borne typhoid fever are now part of sanitary history, small epidemics are still occuring with comparative frequency. Wolman and Gorman * record 242 epidemics of typhoid fever and dysentery which occurred in the United States from 1920–1929, and which were responsible for 9,367 cases of typhoid fever, 84,345 cases of dysentery, and 630 deaths from typhoid fever. During the same decade there were 40 epidemics of water-borne typhoid fever in Canada, resulting in 2,836 cases and 145 deaths. In the United States, 64.9 per cent of the epidemics occurred in cities having a population less than 5,000. In Canada, 77.5 per cent of the epidemics recorded occurred in cities of the same population group. In other words, epidemics of water-borne intestinal diseases have been largely eliminated in the more populous cities and towns through the adoption of modern methods of water purification. In the smaller towns, where adequate funds for water purification purposes may not be so readily available, the problem of water-borne disease must still be considered of primary importance.

Those cities and towns recorded by Wolman and Gorman which experienced epidemics of water-borne typhoid fever during the

* *American Journal of Public Health.* February, 1931, pp. 115–129.

decade, 1920–1929, and where 100 or more cases were reported are as follows: Winona Lake, Ind.; Salem, Ohio; Santa Ana, Calif.; Akron, N.Y.; Olean, N.Y.; Brigham City, Utah; Helena, Mont.; Bloomington, Ill.; Chicago, Ill.; Pittsburgh, Calif.; Salt Lake City, Utah; Fort Wayne, Ind.; Grafton, W.Va.; Alpena, Mich.; Albany, N.Y.; Franklin Boro, N.J.; and Covington and Newport, Ky. In addition the widespread epidemic of water-borne dysentery which occurred in Detroit, Mich., in February, 1926, and which resulted in at least 45,000 cases, should be included in this list. This epidemic, the most extensive outbreak of dysentery on record, occurred in spite of the existence in the city of one of the best, modern rapid sand filter plants, and was apparently due to laxity in control.

Amoebic dysentery and the Chicago World's Fair. — An epidemic of amoebic dysentery, originating in Chicago during the summer and fall of 1933, and spreading to at least 206 cities in the United States, lends further evidence to the fact that only eternal vigilance is the price of safety against the transmission of intestinal diseases through infected water and infected food. Approximately 800 cases occurred between August 16, 1933, and January 24, 1934, and in Chicago alone, fourteen deaths due to amoebic dysentery were reported. By June 5, 1934, 932 cases and 52 deaths throughout the United States and Canada were traced to this epidemic of amoebic dysentery, and at least several hundred additional suspected cases were still under investigation. Approximately one-third of the known cases and deaths occurred in Chicago, and the remainder outside.*

According to reports submitted by the Chicago Health Department and by a special committee † appointed to make an investigation, the epidemic originated in two first class hotels in Chicago and was spread in part by infected food and in part by infected water. The plumbing in these two hotels was antiquated and there were cross-connections between the potable water supply and the sewers and also between the potable water line and other water lines potentially subject to pollution. Evidence was presented to show that on July 2, 1933, two sewer pipes under the ice storage

* H. N. Bundesen, "The Chicago Epidemic of Amoebic Dysentery in 1933," *U.S. Public Health Reports*, v. 49, No 43, Oct. 26, 1934, pp. 1266–1272.

† Herman N. Bundesen, Fred O Tonney, and I. D. Rawlings, "The Outbreak of Amebiasis in Chicago during 1933, Report of a Special Committee on the Amebiasis Outbreak in Chicago," *Jour. A.M.A.*, v. 102, No. 5, pp. 367–372.

rooms in one of the hotels had broken, thus permitting sewage to flood areas where food and ice were stored, prepared, and handled. There were 345 food handlers employed in the flooded area and many of them ate their meals here. This is significant since some of them became ill and others became carriers of amoebic dysentery, and because food served to guests in the hotel was directly infected by the food handlers. Of 1,100 employees in this hotel examination revealed that 165 food handlers and 141 non-food handlers were harboring the Entamoeba histolytica — the causative agent of amoebic dysentery. As a result of the investigation conducted by the Chicago Health Department 1,049 carriers of Entamoeba histolytica were discovered in Chicago. Although 3.9 per cent of the hotel and restaurant employees in Chicago are carriers of Entamoeba histolytica the investigation disclosed the fact that at one time more than 18 per cent of the food handlers in the two hotels where the epidemic occurred were infected.

The Special Committee also found that the two involved hotels used essentially the same water, and that any pollution occurring accidentally in one would affect the supply of the other. The water was obtained from the city mains, but in one of the hotels it was pumped to tanks located on the upper stories of the two hotels. Heavy rains occurring on June 29 and July 2, 1933, flooded the basements of both hotels with sewage, and since cross-connections between the water and sewer lines and between potable water lines and non-potable water lines existed, it is believed that the drinking water in both hotels became infected. Since the epidemic, the cross-connections have been eliminated, and more than a mile of new piping, ranging in diameter from 4 to 15 inches, has been installed in one of the hotels alone. Without this safeguard there is no assurance that similar epidemics will not occur and that many innocent people from all parts of the country will suffer disease and death even as they did in 1933.

CHAPTER X

THE PROTECTION AND PURIFICATION OF PUBLIC WATER SUPPLIES

Public supplies as public dangers. — A public supply is a public danger for two reasons: first, because it affects large numbers of people; and, second, because it is beyond their direct supervision and control. Along with the substitution of the convenience of public for the inconvenience of private supplies of gas, water, milk, and transportation, goes inevitably the surrender of the privilege of private supervision and superintendence. This is one of the obvious disadvantages of urban life everywhere, and especially of life in great cities. The social unit — the family — can as a rule no longer use its own well, its own cow, or always its own carriage. It must depend as a rule upon the public water supply, the public gas supply, the public milk supply, and often on the public vehicle. These, of course, are frequently cheaper and more convenient, but, unhappily, often also more dangerous.

On the other hand it is easy to see that public supplies may easily be made public safeguards. All that is necessary is to substitute for private supervision and private control such expert and scientific superintendence as the danger involved demands, and as far as public supplies are concerned, a condition of the whole may often be obtained far superior to any within the reach of a single member or family of the community. It cannot, therefore, be too soon or too plainly understood that common sense, as well as science, absolutely requires from great cities the most expert public supervision attainable, in place of private supervision surrendered.

The most important public supplies of cities are food, drink, and air. Of these the water supply is easily of the first importance to the sanitarian, for the reason that the air supply is as yet beyond his control, while the food supply, with a few exceptions, such as milk, raw oysters, and certain fruits and vegetables, is purified by cookery before it is swallowed. Water, on the other hand, is swallowed raw in relatively large quantities, and it is now universally

admitted that impure drinking water is a ready vehicle of disease. When we consider the enormous quantities of water required by large cities, most of which is not used for drinking, but all of which must be fit to drink, we may readily appreciate the importance of the subject of water supplies.

The atmosphere as the source of water supply. — The ultimate source of all water supply, public or private, is the atmosphere, in which the vapor of water (derived from land or sea) is condensed and precipitated as rain, snow, dew, or fog. Theoretically, every raindrop must form about some material particle, and the only particles of this kind in the atmosphere are particles of dust. Dust particles are frequently associated with the bodies of microorganisms, and hence it follows that at the very instant of its birth the raindrop may enclose one or many microörganisms. On the other hand such bacterial bodies may not be alive but dead; and dust consists of many other things than microorganisms, bits of inorganic and organic matter, so that only a few raindrops, probably, can be conceived of as including microorganisms, still less living microorganisms, at the start. Again, it must not be forgotten that even if we assume the presence of some living microorganisms in raindrops, these are doubtless, with the rarest exceptions, saprophytic and not pathogenic. As the rain falls into the lower layers of the atmosphere, richer in dust, the chance of such pollution necessarily increases. The possibility of such atmospheric infection is, however, very remote and except in unusual cases must be regarded as unimportant.

The pollution of snow by dust. — The phenomena afforded by snow deserve especial, though brief, mention in this connection. A snowflake, especially if moist, appears to be a kind of filter through which a relatively large amount of air passes as it falls; and this peculiarity of structure doubtless explains the fact that snow, particularly that first to fall, is often really dirty and rich in microorganisms; while, at the same time, the atmosphere, after a prolonged snowfall, is bacterially, as well as to the senses, noticeably purified. It follows as a matter of course that melted snow or snow water is far from pure; and that the water derived from melted snow in periods of "thaw" is not, as might be supposed, particularly pure.

Influence of the earth upon the purity of rain water. — Once the raindrop touches the surface of the earth or its appurtenances

— such as rocks, trees, roofs, fences, haystacks, animals — it meets, almost immediately, abundant dust or dirt, including matters organic and inorganic, soluble and insoluble, living and lifeless. As it rolls over the dusty rock alone, or as a trickling stream, it naturally dissolves some substances and sweeps on others mechanically — its departure from purity increasing as it proceeds. If it wears away the soil enough of the latter may be carried along to make it discolored or even muddy, no chemical analysis of such water being needed to show its pollution, while bacterially it is charged with thousands of microorganisms in every cubic centimeter. If, on the contrary, the raindrop falls upon porous, absorbent earth, not already water-logged, it will sink by gravity, possibly also by capillarity, or by the push of other particles from behind, down into the spongy earth. Here, also, it will as a rule come into contact with matters organic and inorganic, soluble and insoluble, living and lifeless. Whether its alighting place be sand or soil it will usually find the porous earthy particles mantled with bacterial jelly, dead or alive, wet or dry. And immediately actions and reactions, physical and chemical, will begin, and continue until a new condition has arisen. Water which takes the vertical direction on touching the earth is commonly called "ground" water; that which moves off quickly more or less horizontally is called "surface" water. Both, it will be observed, are comparatively impure when they arrive on the earth. However, the terms "pure" and "impure" are relative only, and in the popular sense, rain water before it touches the earth's surface is usually remarkably pure.

Rain water and the living earth. — Rain water on entering porous earth (either sand or soil open or close in texture) is at once brought under new conditions and into close contact with swarming bacterial life. The earth is the home of the bacteria. They are found in the air, but only because they have been lifted into it by winds, in the form of dried earth or dust. They are found in water — in streams, lakes, and the sea — but seldom in density of population at all comparable to that existing in the surface layers of the earth. The reason for this seems to be that at the surface of the earth bacteria secure at the same time oxygen, moisture, and food — the most favorable conditions for their life. It is true that bacteria are not entirely aquatic. Many species seem to inhabit the surface layers of the earth and are largely and perhaps prefer-

ably terrestrial. This, as we shall see, is a matter of great consequence in the establishment and conservation of the purity of waters.

The raindrop arriving upon the porous earth comes in contact at once with a large population of bacteria resident on the sand grains over which it is spread. More or less slowly it sinks through this living, gelatinous layer, and as it passes on it is robbed of its suspended organic matters and of some of those in solution. It is also mechanically filtered to some extent, no doubt; but the main thing is that as a result of its journey, it is so purified in respect to its organic matters that it can no longer support abundant bacterial life of certain types. Meanwhile it readily dissolves the end results and the by-products of the luxuriant bacterial vegetation through which it passes, and becomes the vehicle of carbonates, nitrates, sulphates, chlorides, and other mineral matters. As it sinks lower and lower it dissolves more and more of such salts, and at the same time, is increasingly purified of organic matters capable of supporting bacterial life. Such water may also contain bacteria, but they are relatively few in number and singularly slow of development. Water derived from deep wells, if unpolluted, has a low bacterial content, and the organisms found are different than the ordinary bacteria. In most ground waters a high degree of organic purity is established, and if such waters be collected in protected springs, wells, or covered reservoirs properly constructed, their organic purity is readily conserved, and they constitute some of the most satisfactory water supplies we have.

There are, however, certain conditions which limit the usefulness of "ground" waters. While of high organic purity they may have become so rich in inorganic matters as to belong to the class of "hard" or "mineral" waters which places them in the category of undesirable waters for public supplies. Far more important, however, is the fact that such waters are necessarily limited in quantity and, therefore, not often feasible as a source of water supplies for great cities.

On the other hand and under certain circumstances ground waters may be polluted instead of purified by their passage through the earth. If the earth is itself impure or overtaxed from leaky cesspools, sink drains, or other sources of foulness, natural purification may give way to unnatural pollution. This is one way by which domestic wells may become polluted. But, in view of the re-

markable purifying powers of the earth, and the lack of satisfactory evidence that many cases of disease arise in this way, it is probably true that damage done by the underground pollution of domestic wells has been greatly exaggerated. Excepting in those rare cases where fissures in the earth occur, which give easy access for pollution from the surface, and except where pollution has occurred from the open top, it is doubtful whether much danger can be attributed to ground water supplies obtained from properly constructed domestic wells. Much more serious than pollutions from the soil are the dangers of infection of ground waters from workmen within wells themselves. This must be prevented at all costs.

Ground waters also have the defect in common with all stored waters that in order to remain potable after collection and storage they require to be kept in the dark. On exposure to the light in open reservoirs ground waters often become infested with chlorophyll-bearing microscopical organisms (diatoms, desmids, etc.), which in turn support noxious infusorial animals, and give rise, not infrequently, to highly disagreeable and even nauseous tastes and odors, sometimes described by the consumers of the waters as resembling "cucumbers," "fish-oils," "pigpens," etc. The conservation of the purity of ground waters thus often becomes a matter requiring expert treatment.

Surface waters and their pollution. — Surface waters which are already more or less impure from aërial pollution, instead of being subjected immediately to a progressive purification by sinking into the earth, move along the surface of the earth, which they erode, growing in volume as they proceed, and forming rills, rivulets, or larger streams — brooks, creeks, and rivers — which still continue to move along the earth's surface, exposed to all sorts of pollution, until they pause for a longer or shorter time in ponds and lakes, or finally join the sea. The area over which this process goes on is called a "watershed."

It would be a mistake to suppose, however, that the entire volume of water in brooks, rivers, and lakes has been thus derived. A considerable portion, even of the so-called "surface" waters, except in times of freshet due to sudden thaws or to heavy and prolonged rain, is really ground water, purified by a shorter or longer passage through the porous earth. Since all rivers, streams, ponds, and lakes contain varying quantities of pure ground water, this fact alone serves to show how very impure the really surface-water

portion of such streams must be. A water derived from a quick-spilling watershed must always be regarded as relatively impure and dangerous.

The "self-purification of streams" again. — How, then, did it ever happen that many well-regulated American cities have in the past drawn their water supplies from polluted rivers or lakes, not heedlessly, but on the advice of the ablest engineers and sanitarians of the day? The answer is that these engineers, in common with the best sanitarians of the time, trusted to a theory of the establishment of purity in surface waters, which we now know to have been only a half-truth and utterly untenable; namely, the theory of "self-purification" of streams. In substance this theory was that "running water purifies itself." It was based on the obvious fact that a stream befouled at a certain point often shows no visible sign of such defilement at places some distance below. It was powerfully supported by the chemistry of the day, which sufficed to show, in correspondence with the evidence of the senses, that there was actually less organic matter at the lower than the higher point.

Today we realize that this theory is only half true, and that such self-purification is only partial and absolutely unreliable. By a curious reversal of scientific opinion, we now hold that it is precisely "running" water which is least likely to purify itself, while stagnant (standing) water — formerly looked upon with dread and suspicion — is now in much favor.

The source of error in the earlier practice was the assignment to true purification and actual chemical change of what was really for the most part the effect of dilution with purer water. But even more than this occurs, for some of the pathogenic organisms in polluted streams disappear *en route* because of unfavorable temperatures, lack of proper food, entanglement with heavier suspended particles that settle to the bottom, or because of the action of predatory algae and protozoa, the germicidal influence of sunlight, or other conditions, all of which may be summed up in the words "unfavorable environment." Obviously, the more rapid the stream, the less these purifying forces can act, and the more certain the damage likely to be done to the consumers of the water below.

Quiet water, not running water, purifies itself. — It is therefore not so true that "running" water, as that quiet water, purifies

itself. We may even go so far as to say that the first requirement for the natural establishment of purity in surface waters is quiescence. But quiescence in rivers is ordinarily impossible. Hence the establishment and conservation of purity in rapid rivers is today regarded as, by natural means, impossible; and no river, unless from an absolutely uninhabited watershed, is to be regarded as suitable for direct use as a public water supply. In the case of lakes and ponds, natural storage and underground dilution help to improve the quality of the water. In rivers, artificial storage or artificial purification must be employed if the water is to be used for drinking.

Purification by storage. — If a running water such as we have in a river can be converted into a quiet water — as in a reservoir — then purification may result. This is, indeed, what takes place with water derived from polluted watersheds and stored in huge reservoirs — great and often adequate purification may be established by prolonged quiescence, or storage. The bacteria present are eliminated by the factors enumerated above until finally only those remain which can permanently thrive in the now relatively pure water; and these are apparently mostly harmless.

Purification by slow sand filtration. — It follows as a matter of course from what has now been said, that if a city or town must use a river as its source of supply, it must ordinarily first purify it if storage alone is inadequate. One of the methods still in use to some extent in New England is slow sand filtration. Here purification is accomplished precisely as is the case with the rain falling on porous earth.

Land of porous texture is first prepared, sand having been found preferable for the purpose, while in the best practice, specially constructed "areas" or "beds" of sand are made and then thoroughly underdrained so as to facilitate the collection of the purified water. After the bed is filled with water from below, the water to be filtered is allowed to run over the surface and find its way down through the open, porous sand. Very soon, however, bacteria take up their residence on the sand grains, especially near the top, bacterial jelly accumulates, and a purifying mechanism or organism of great efficiency results.

Innumerable tests of such mechanisms as this have been made and their high efficiency shown. They are usually called sand "filters," but the name is unfortunate as implying something

artificial rather than natural. The process is, in fact, nearly if not exactly the same as in the purifying of surface waters which pass through earth and become ground waters, although by selecting the porous materials, "hardness" and some other faults of ground water are avoided. It is by such means that London, Hamburg, Berlin, and Lawrence in Massachusetts, secure from polluted surface waters satisfactory and sanitary supplies. Albany, Washington, Providence, and Pittsburgh followed in their footsteps, and many other American cities did likewise. Some of these have subsequently abandoned slow sand filtration in favor of rapid sand filtration and chlorination. We may conclude, however, that for the establishment of purity in surface waters, there are two important natural processes — "storage" and "sand filtration."

Other processes of purification of water supplies. – While it is of academic interest to consider slow sand filtration as a natural method of purification, in reality it is an artificial process. Basins are carefully prepared and underdrained for slow sand filters, the sand is carefully selected and graded, the rate of operation is controlled, and the operation of the filter is under constant supervision. The effective purifying medium — the bacterial jelly surrounding each sand grain — is built up naturally. That is the main reason why this method of water purification has often been referred to as a natural process Other processes, equally artificial and perhaps more so, and subject even to greater regulation and scientific control, have come into use, and among those thus far proposed, rapid sand filtration has gained great popularity in America. The following advantages are claimed for this method of treatment: first, rapidity; second, bacterial efficiency; third, removal of clayey turbidities and thorough decolorization; and fourth, convenience of installation. The principles involved in rapid sand filtration are as follows. A chemical reagent of presumably harmless character, such as aluminum sulphate, is added in small doses to the water under treatment, but sufficient in quantity to produce, if the reaction of the water be right, a flocculent precipitate. If after thorough mixing, the water is kept relatively quiet, or is allowed to stand, this precipitate entangles and carries to the bottom a large amount of the suspended matters present, including the bacteria. However, enough of the floc is retained in the water and is allowed to pass on to the filter. The sand grains become coated with this artificial jelly-like material

while the water passes rapidly through the filter. The larger suspended particles, including some bacteria, may be strained out or caught in the intricate labyrinths between the sand grains, but the bulk of the bacteria and other colloidal particles, like those which give color to the water, are removed by adsorption with the jelly-like coating on the sand grains. When the filter becomes sufficiently clogged, as indicated by special devices known as loss of head gauges, the filter is washed by shutting off the incoming water and reversing the flow of water in the filter. When the washing has been completed the process of filtration is resumed. In this way water is filtered rapidly and effectively, but its safety is always insured nowadays by subsequent disinfection with liquid chlorine. For muddy waters and waters high in color this method of purification is the only one that is really applicable. It is in use today throughout the greater portion of the United States. Even in New England where the waters are comparatively free of color and turbidity, it is gradually replacing slow sand filtration. Albany, Providence, and Washington have recently supplemented their slow sand filters with rapid sand filters, and when Cambridge, Mass., decided to purify its water supply it adopted rapid sand filtration at the very start.

Tastes and odors in water supplies. — With the improvement in the standards required of drinking water supplies greater emphasis has been placed on the question of tastes and odors associated with drinking water. In part this has been due to unfortunate conditions which have developed in connection with some of our largest and best water supplies, as exemplified by the experience of New York in 1921, and by the Spot Pond water serving part of the Boston North Metropolitan District in 1932. Each case received prominent publicity and focused the attention of sanitarians and laity on an important municipal sanitary problem. Furthermore, in the middle west, and especially along the Ohio River, where water for large cities is derived from streams polluted with sewage and industrial wastes, certain medicinal odors have been readily detectable following the application of chlorine. This condition likewise arrested attention, resulted in scientific inquiries, and finally in the solution of a vexing problem.

Every potable water has a natural, pleasant taste due to the solution of oxygen and carbon dioxide. The flat taste of distilled water is due to the lack of sufficient dissolved oxygen. Such waters

can be improved in taste by aëration. There are, however, other tastes and odors in water supplies which are highly objectionable. Some of these are sometimes due to the solution of certain gases such as hydrogen sulphide, which can also be readily removed by aëration, but in the great majority of cases the undesirable tastes and odors are due to the growth of certain algae, especially the blue-green algae (cyanophyceae), diatoms, and infusoria.

These organisms usually make their appearance in water supplies during the summer and fall months — although some of the troublesome protozoa, like synura and uroglena, prefer the colder months of the year — and are found especially in stored waters which have direct access to sunlight. Frequently, too, they are found in the waters on filters, and in such cases, they serve not only to impart their characteristic undesirable tastes and odors, but also to clog the filters, so that frequent cleaning becomes necessary. While they are unable to produce any communicable disease, they are responsible for curtailing the amount of water consumed for drinking purposes at such times, and they are more responsible for the development of a popular interest and concern in the public water supply than any other single factor. If typhoid bacilli produced tastes and odors in water supplies, the control of waterborne typhoid fever would be accomplished expeditiously.

These tastes and odors in water supplies are due to little drops of oil secreted by the microorganisms involved. Fishy, grassy, oily, sweet, geranium-like, pigpen, ripe cucumber, and other obnoxious tastes and odors may be produced. To combat them the reservoir is sometimes "stripped" to remove the organic matter in the surface layer of soil on which the microorganisms are dependent for food. This precaution which aims at preventing the development of the organisms involved is quite expensive and is not always successful. This was done when the Wachusett reservoir which supplies water to the city of Boston was constructed. Aëration is also employed; and sometimes, in the case of filters, covers are provided to prevent direct access to sunlight.

In the great majority of instances, however, it is necessary to use copper sulphate, although in recent years chlorine has been substituted in some instances. The copper sulphate is dissolved in sufficient concentration to make it effective as an algicide and yet not strong enough to destroy fish life. The copper sulphate is usually dissolved by towing it in canvas bags at the end of a row

boat or motor launch around the lake or reservoir under treatment Such treatment destroys the organisms responsible for tastes and odors, but does not remove the tastes and odors already present. These are remedied only by aëration, or by dilution, or by treatment with activated carbon. Unless used as a preventive, copper sulphate therefore does not give immediate relief from tastes and odors. The best practice today calls for daily microscopical examinations of drinking waters that are subject to tastes and odors, and the identification and enumeration of each organism present. When certain organisms like synura and uroglena appear, or when other taste-producing organisms attain a definite concentration, preventive treatment with copper sulphate or chlorine or chlorine and ammonia is indicated. In this way vast populations can be spared the inconvenience and hazards of an interruption in the use of the regular municipal water supply. The first to call attention to the value of copper sulphate in the treatment of drinking water in order to combat tastes and odors due to the growth of certain microorganisms were Dr. George T. Moore, and Dr. Karl F. Kellerman, of the Bureau of Plant Industry, U.S. Department of Agriculture, who published a report on this subject in 1904.

Although the li.t of organisms capable of producing undesirable tastes and odors in drinking water is very long, it may be of interest to mention some of the more important ones and to give the odors they produce. Among the diatomaceae are asterionella (aromatic, geranium, fishy), meridion (aromatic), navicula, and tabellaria (aromatic, geranium, fishy); among the chlorophyceae are cladophora, conferva, desmidium, eudorina (faintly fishy), pandorina (faintly fishy), spirogyra, volvox (fishy), and zygnema; among the cyanophyceae are anabena (moldy, grassy, nasturtium, vile), aphanizomenon (moldy, grassy, nasturtium, vile), clathrocystis (sweet grassy, vile), coelosphaerium (sweet grassy), and rivularia (moldy, grassy); and among the protozoa are bursaria (Irish moss, saltmarsh, fishy), cryptomonas (candied violets), dinobryon (aromatic, violets, fishy), euglena, synura (cucumber, muskmelon, fishy, bitter), and uroglena (fishy, oily, cod liver oil).

Certain tastes and odors in water supplies have developed as a result of the formation of chloro-compounds with organic matter or with insignificantly small amounts of phenols or cresols present when chlorine disinfection was employed. Where water supplies have been contaminated with coke oven wastes from steel mills or

public service corporations the problem has been a serious one. A medicinal, iodoform-like taste and odor is produced which is highly objectionable. In such instances the odor can sometimes be eliminated or destroyed by superchlorination, *i.e.*, treatment with excess amounts of chlorine, and then removing the excess chlorine by dechlorination. Dechlorination can be accomplished with sulphur dioxide or by using sodium sulphite, sodium bisulphite, or sodium thiosulphate. Care must be exercised, however, not to dechlorinate to such a degree that the protective value of chlorine as a disinfectant has been destroyed. In order to overcome the undesirable aspects of dechlorination and to eliminate the formation of objectionable end-products when chlorine is used as a disinfectant in such cases referred to above, chloramine has been recommended. This compound is formed as a result of the union that takes place when ammonia and chlorine are brought together. Chloramine is an effective germicide; it does not react with organic matter or with phenols and cresols to produce objectionable tastes and odors, and it possesses a latent or residual germicidal effect which is helpful in eliminating bacterial after-growths in reservoirs or water systems.

The latest method employed in combating tastes and odors in drinking water consists of the use of activated carbon. This is composed of finely divided particles of carbon, which have a great surface area, and which possess the property of removing tastes and odors in water supplies by adsorption. Activated carbon can be employed in the form of filters or as has been the case more recently, it is introduced directly into chemically coagulated waters after sedimentation has taken place, and allowed to flow on to the rapid sand filters. Here the activated carbon is removed after it has done its work and is wasted when the filter is washed. Its extensive use in the United States today is evident testimony of its effectiveness.

Sanitary protection and inspection of watersheds. — Experience has taught us that serious pollutions may occur in surface supplies from the temporary residence on the watershed of thousands of laborers, some of whom may be walking cases of typhoid fever and other intestinal diseases; or by the use of watersheds, lakes, and ponds for picnic purposes, boating, bathing, hunting, and other recreational pursuits. The latter hazard was called to the attention of the Massachusetts State Board of Health as early as 1896, and some attempt was made at the time to clean up the

dangerous pollutions that existed in certain watersheds and which seriously imperiled the purity of the supplies with which they were connected. The development of electric and steam railway systems, and more recently the widespread use of automobiles and buses, and the construction of excellent roads, have caused many new "resorts" to spring up in out-of-the-way places (often chosen largely because of their isolation and wildness), and in not a few cases on or near lakes and reservoirs used for water supplies, or upon their watersheds. As a result there is hardly a water supply, no matter how isolated it may be, that is not subject to serious potential pollution at the present time.

Far more serious, of course, are those instances in which villages or towns are situated within or upon a watershed. These cases often require the most careful study and supervision. Sometimes it is necessary and possible to divert their drainage from the watershed; sometimes, when this is impracticable, it can be purified on intermittent sand filters or by other suitable sewage treatment facilities within the watershed. Here again intelligent supervision and control are required, and these must be permanent, inasmuch as the conditions on the watershed are subject to frequent and often unexpected change. It is not enough to burn occasionally a few barns or to purchase and remove a few pigpens on the watershed. The problem is larger than this, and requires thoughtful, enlightened, and continuous public service for its proper amelioration.

After the careful collection of the water from the watershed it should be subjected to storage and artificial purification by filtration, if necessary — in order to correct whatever defects it may still possess. If it be a ground water further filtration is generally unnecessary. If it be a surface water it should, if possible, be stored for an adequate period and probably also filtered either on slow or rapid sand filters. In any case it is doubtful whether the safety of a city water supply can be insured without adequate disinfection. Today this is usually accomplished with the aid of liquid chlorine. Chlorination bears a relationship to the safety of water supplies as pasteurization does to the safety of city milk supplies.

Disinfection of drinking water. Use of chlorine and chlorine compounds. — In spite of the care with which a water supply may be selected, and the efficiency of the treatment to which it may be submitted, no absolute reliance can be placed on the

safety of the water all the time. The validity of this attitude is especially apparent in the production of certified milk, where in spite of all the sanitary precautions observed, and in spite of the medical supervision of all employees and the veterinary supervision over all cows, epidemics of septic sore throat, typhoid fever, and other diseases have been associated with such excellent milk supplies when consumed raw. As noted above, what pasteurization is to the milk supply of a community, disinfection is to its water supply. In both cases the germicidal agency employed simply insures the safety of the food against microbial infection. It does not purify the water or milk in any way. It simply destroys all or most of the living bacteria that may be present. There are some instances still where public water supplies are obtained from surface sources and are not disinfected but where the typhoid fever incidence is extremely low. Such cases are rare in the United States and are gradually disappearing. In such cases, however, protection of the community is usually provided by prolonged storage. For the great majority of cities in the United States reliance on the ultimate safety of the drinking water is placed on chlorination.

It is well that it is so, for water is one of the few remaining foods of mankind that is still largely consumed in the raw state. In the Orient, where water supplies are not purified with the same frequency as in the United States, people have learned by experience that the only way to safeguard their drinking water under such conditions is to boil it. Accordingly very little water is consumed raw but most of it is used in the form of tea prepared with boiled water.

The means employed for disinfecting public water supplies in the United States consists in the use of chlorine or compounds containing chlorine. In Europe, and especially on the continent, some important municipal water supplies such as those at Paris, Lille, Florence, Nice, Wiesbaden, Budapest, and Leningrad are disinfected with ozone. In the United States, however, ozone has not been employed except in a limited way, and that for the disinfection of swimming pools. The same is true for disinfection with ultraviolet rays.

Chlorine was discovered in 1774 by the Swedish pharmacist, Scheele. In 1810 Sir Humphrey Davy proved it to be an element. It was Michael Faraday, however, who, early in the nineteenth century, demonstrated how to liquefy chlorine, and thus paved

the way to the use of modern methods for its distribution. Liquefied chlorine for commercial purposes became available in cylinders in 1910.

Chlorine was first used for disinfecting water in the form of chloride of lime. This compound is also known as bleaching powder and as calcium hypochlorite. In 1896 George W. Fuller applied chloride of lime to the raw water flowing on to his experimental rapid sand filters at Louisville with favorable results. In 1897 a solution of sodium hypochlorite was introduced directly into the water supply of Maidstone, England, as a means of controlling a water-borne epidemic of typhoid fever. In 1902 Dr. Duyk of Belgium applied ferric chloride and chlorinated lime to the raw waters of Middlekirke for coagulation and sterilization. In 1904 and 1905 Sir Alexander Houston of the London Metropolitan Water Board, employed sodium hypochlorite to disinfect the water flowing on to the slow sand filters at Lincoln, England, while in 1906, Professor E. B. Phelps conducted experiments at the Massachusetts Institute of Technology in which he showed that a solution of hypochlorite of lime could be used effectively for the complete or nearly complete elimination of the bacteria in sewage and sewage effluents. In 1908 George A. Johnson applied a solution of hypochlorite of lime to the heavily polluted waters of Bubbly Creek, Chicago, prior to filtration, and demonstrated that objectionable decomposition could be arrested in this way. It was not, however, until the famous East Jersey Water Company case was decided by legal decision in May, 1910, that the disinfection of municipal drinking water became recognized as a safe, reliable, and harmless method of treatment. Since then disinfection with liquid chlorine especially has spread very rapidly throughout the United States, and in fact, throughout the civilized world.

The East Jersey Water Company was supplying Jersey City with water derived from the Rockaway River and stored in a large reservoir at Boonton, 23 miles west of the city. In May, 1908, upon a decision of the court, the water supply was found to be polluted with sewage, and the company was ordered to render the water pure and safe. Filtration or any other specific method of treatment was not required. At the suggestion of Johnson and Leal disinfection with hypochlorite of lime was employed, and it was found that the bacteria indicative of fecal or sewage pollution could be eliminated in this way. When the court de-

cided to hear evidence in order to ascertain whether its decree had been complied with, much testimony was presented both for and against the method of treatment adopted. Finally, in May, 1910, the court rendered an opinion favorable to chlorination, and a portion of the decision is especially worth noting here, since it summarizes the expert testimony presented.*

"From the proofs before me of the constant observations of the effects of this device, I am of the opinion and find that it is an effective process, which destroys in the water the germs, the presence of which is deemed to indicate danger, including the pathogenic germs, so that the water after treatment attains a purity much beyond that attained in water supplies of other municipalities. The reduction and practical elimination of such germs from the water was shown to be substantially continuous. Upon the proofs before me, I also find that the solution described leaves no deleterious substances in the water. It does produce a slight increase in hardness, but the increase is so slight as in my judgment to be negligible. I do therefore find and report that this device is capable of rendering the water delivered to Jersey City pure and wholesome for the purposes for which it is intended, and is effective in removing from the water those dangerous germs which were deemed by the decree to possibly exist therein at certain times."

It was not long after this, in fact during the same year, 1910, that Major C. R. Darnall of the U.S. Army Medical Corps demonstrated at Fort Meyer, Virginia, that when liquid chlorine was applied to an alum treated water it brought about an almost complete elimination of the bacteria present without imparting to it any taste or odor. Since liquid chlorine can be stored without any loss of strength, since it eliminated the sludge problem associated with the use of calcium hypochlorite, since the dose could be regulated more easily and accurately than when a solution of hypochlorite of lime was employed, and since the application of liquid chlorine was more effective, and cheaper, and did not require the storage space necessary for the use of hypochlorite of lime — for all of these reasons, liquid chlorine replaced hypochlorite of lime very rapidly. Today, through the development of special machines, easy to operate and regulate, chlorine is added to the

* George A. Johnson, "The Purification of Public Water Supplies," *U. S. Geological Survey Water Supply Paper*, No. 315, 1913.

water supplies of New York, Chicago, Philadelphia, Detroit, Washington, and hundreds of communities all over the United States. The application of such small amounts of chlorine as 0.2 to 0.5 part per million, or from 1.5 to 4.0 lbs. of liquid chlorine per million gallons of water, is sufficient to render a relatively clear water, free from large amounts of organic matter, entirely safe from a bacteriological standpoint.

There are times, however, when hypochlorite of lime still serves a useful purpose. During flood, fire, or earthquake, during war or other great emergency, when the facilities of organized civilized life may not be available, hypochlorite of lime can be employed quite readily for disinfecting water. It is also an effective agent for sterilizing typhoid stools and other infected body wastes. Liquid chlorine and hypochlorite of lime represent cheap and unusually effective germicidal agents.

The uses of liquid chlorine at present are numerous. Not only is it used for disinfecting water, sewage, and sewage effluents, but it is used in sterilizing milk bottles, in combating tastes and odors in water supplies, in controlling the prevalence of the psychoda fly or filter fly in the vicinity of trickling filters, in preventing ponding or pooling on trickling filters, in diminishing the oxygen demand of polluted waters, in combating hydrogen sulphide odors in sewers and sewage tanks, in delaying active decomposition where pollution has occurred, in the preparation of the Carrel-Dakin solution for disinfecting wounds, and in a host of other ways. It comes in iron or steel cylinders containing 100 or 150 pounds, or it may be shipped in steel drums or even in tank cars. During the war liquid chlorine was one of the articles placed on the preferred list for shipment on the railroads in the United States because of its important relationship to the health of the civilian population.

The mechanism by which chlorine brings about germicidal action is still undetermined. It is believed by some that the bacteria are destroyed because of the direct toxic effect of the chlorine. Others maintain that the introduction of chlorine into water results in the formation of hypochlorous acid — an unstable compound — which breaks up and liberates nascent oxygen and hydrochloric acid, the supposition being that the bacteria are destroyed by the nascent oxygen. Still others maintain that the chlorine combines with ammoniacal substances in the water to

produce chloramines, and that the toxic effect is brought about in this way. Since chlorine compounds can destroy bacteria even when oxygen is not liberated it would seem that those mechanisms that explain the germicidal action of chlorine without hypothesizing the formation of nascent oxygen have a more sound scientific basis.

Finally, it must be remembered that the purpose of chlorination in connection with municipal water supplies is essentially disinfection, and that in order to disinfect most conveniently and effectively, it is necessary for the water to be as free as possible from organic matter, turbidity, and color. In the presence of these substances the chlorine will first be utilized to satisfy their "chlorine demand," so that larger quantities of chlorine will be required for disinfection. Furthermore, in the presence of foreign substances, the bacteria in water may be protected mechanically against the action of the chlorine Also, if large doses of chlorine are employed, objectionable chlorine tastes and odors may be produced or the chlorine may enter into combination with the organic matter present to produce undesirable tastes and odors. The inevitable conclusion, therefore, is that liquid chlorine employed for disinfection should be applied to a water supply free of turbidity, color, and organic pollution, and already purified to as high a degree as possible. Chlorination cannot take the place of coagulation, filtration, sedimentation, or selection in the treatment of water supplies. It is used simply to reenforce their qualities and to insure safety against the microbial diseases associated with drinking water. Used in this way it is an unfailing and effective weapon in man's control over water-borne diseases.

CHAPTER XI

ICE AS A VEHICLE OF DISEASE

The mingling of melted ice with food and drink. — The almost universal American custom of cooling certain drinks — such as water, lemonade, and tea — by adding to them lumps of ice, which are allowed to melt and mingle with liquid to be swallowed, early attracted the attention of sanitarians, to whom the idea naturally occurred that if the ice thus added be impure, serious consequences may result. The amount of ice consumed in this way in America during the warm season, and indeed throughout the year, is simply enormous. It is the almost invariable rule in hotels and restaurants to begin the service of a guest at table by filling his glass with broken pieces of ice or "cracked" ice. Pleasure parties, excursion parties, and the like, often make use of large tubs of drink (water, lemonade, orangeade, punch, etc.), into which a cake of ice is put bodily; and this, in melting, not only cools the surrounding liquid, but contributes to it whatever impurities it may contain. Raw oysters (removed from the shell) are sometimes placed upon a luncheon or dinner table in a cubical cavity, cut into the top of a large block of ice, and are later served with more or less of the meltings of the sides and bottom of the ice-cavity in which they lie. It is plain that if the germs of disease or other impurities can survive in ice, it may form a ready vehicle for the distribution of disease.

Does polluted water purify itself in freezing? — It is a popular belief that the ice which forms upon a body of water is purer than the water itself. This belief is probably based in part upon the well-known fact that when a substance crystallizes out of a liquid the crystals formed are usually purer than the mother-liquor from which they come; and general reliance seems to have been placed upon this tendency to purification to which ice crystals also might be expected to be subject, until, in 1887, careful investigations by Prudden showed that bacteria are not wholly eliminated from ice in the freezing of water, and that these may even survive in ice for long periods. It was then remarked that ice often

contains visible impurities, and if these, why not also others invisible?

A little reflection will show that the question of elimination of impurities such as bacteria, which are really suspended particles, depends for its solution upon a variety of conditions. If, for example, the body of water, *e.g.*, a small lake or pond, containing bacteria be frozen absolutely solid, there is no reason to expect elimination during crystallization, for there is no place into which the bacteria can be extruded by the growing crystals. But if the ice in question is formed on the surface of a quiet lake or pond, the very first skimming of crystals produces absolute quiescence in the underlying layers of water, and gravity must then exert its effect upon the floating bacteria. In this case there is abundant opportunity for the elimination of foreign particles by the growing crystals; and as these gradually extend downward they will naturally first invade those layers of water nearest to themselves, which, for obvious reasons may be the freest from bacteria, while the lower layers of the pond will contain not only the bacteria belonging to themselves, but also such as have been dragged down by gravity from the upper layers. Accordingly the uppermost layer of such ice will often be the richest in bacteria; while the next lower ice layers, especially if their formation has been slow, may be relatively free from bacteria.

Again, to take another case: If, as is often done, the harvesters, after a few inches of ice have been formed, cut holes in the ice-sheet, allowing the subnatant water to overflow it, and by freezing solidly from above to become added bodily to that already formed, the mass will be frozen as a whole, and no mechanical elimination during crystallization can reasonably be expected. Lastly, if, after the ice has begun to form, snow falls upon it, and this, by a rainfall or a thaw followed by freezing weather, becomes added as a superficial layer of "snow-ice" to that upon which it fell, such "snow-ice" may be expected, from what has been said above in regard to the action of snow as an atmospheric filter, to contain large numbers of bacteria.

From these various considerations we may conclude that the answer to the question, Does water purify itself in freezing? depends largely upon the conditions under which it is frozen. If ice is formed upon a quiet lake or pond of considerable depth, the water of the pond probably does purify itself to a marked degree

in freezing. But if, on the other hand, the freezing takes place in such a way that sedimentation has little influence, or if an entire mass of water is frozen solid, purification may be much less marked, or even largely wanting.

Epidemics attributed to infected ice. — In spite of the fact that ice may contain very considerable numbers of bacteria, and that it has been hitherto regarded as a dangerous vehicle of disease, only a surprisingly small number of epidemics have been charged to infected ice; and a careful examination of the reports of these leaves upon the student the impression that the dangers of polluted ice have probably been exaggerated.

Among the well-known epidemics of typhoid fever or intestinal disorders which have been associated with the use of polluted and infected ice are the following. In 1875 an epidemic of a severe intestinal disorder broke out among the guests at one of the large hotels at Rye Beach, N.H. After investigation it was concluded that infected ice was the cause. In 1901 Dr. W. H. Park described an epidemic of typhoid fever which he believes was due to the use of infected ice obtained from a highly polluted pond. In 1898 Dorange described an epidemic of typhoid fever, presumably due to ice, which occurred among eight lieutenants of a regiment stationed at Rennes, in the fall of 1895. In 1903 Hutchins and Wheeler gave one of the most convincing accounts of an epidemic of typhoid fever presumably due to the use of infected ice, which resulted in 39 cases, and which occurred at the St. Lawrence State Hospital, three miles below Ogdensburg, N.Y. Although the typhoid bacillus was isolated from "black or dark brown granular matter," found in the ice under suspicion, and verified by serum agglutination tests, Dr. H. W. Hill, who subsequently reviewed the epidemiological evidence, is of the opinion that the outbreak was caused by a carrier rather than by the infected ice. One of the most recent outbreaks of typhoid fever, presumably due to the use of infected ice, occurred at Elmira, N.Y., during the summer of 1923, and resulted in 37 cases. The epidemic was reported by Conway in the *American Journal of Public Health* for 1924.

Reviewing the evidence, it seems probable that certain intestinal disorders caused by decomposing organic matters, if not by the more well-defined pathogenic germs, have at times been caused by polluted ice. On the other hand there is not much satisfactory evidence that typhoid fever or other well-known communicable

diseases are carried in this way. Natural ice obtained from polluted rivers, lakes, and ponds, has been used for years, without resulting, with the advent of warmer weather, in definite, marked outbreaks of typhoid fever which could be unquestionably ascribed to the use of the polluted ice. However, the possibility that some obscure sporadic cases have occurred in this way cannot be denied.

Investigations of the purity of ice. — As early as 1871 Professor Burdon-Sanderson observed that (liquid) culture media showed bacterial growth when inoculated with melted snow or ice. Von Frisch froze putrefying solutions, subjected the frozen mass to a temperature of −87° C. and after the lapse of some hours found that sterilization had not been effected. Cultures of bacteria have been kept at a temperature of −253° C. for several hours without producing sterilization. Samples of ice cream infected with living typhoid bacilli and stored at −4.0° C. still showed the presence of living typhoid germs at the end of 2.5 years.

Professor Joseph Leidy in 1884 exhibited at a meeting of the Academy of Natural Sciences of Philadelphia, water derived from melted ice containing not only living infusoria but also rotifers and other worms. Pictet and Young subjected various species of bacteria to a temperature below −70° C. for 108 hours (during 20 hours below −130° C.) and found that after this treatment cultures of *B. anthracis* were alive and virulent. Kowalski analyzed 60 specimens of natural ice and obtained from 10 to 1,000 bacteria per cubic centimeter, no specimen being sterile. Schmelk studied the bacterial life in the snow (and ice) of a Norwegian glacier and in the cold streams flowing from it. Bujwid found 21,000 bacteria per cubic centimeter in a melted hailstone, and similar though smaller figures have been obtained by others (Foutin, Abbott). Heyrothin, 1888–1889, obtained in the ice supply of Berlin from 2 to 133,000 bacteria per cubic centimeter, the highest figures corresponding to the most marked pollution. Prudden, in 1887, found in the natural ice supplied to New York City a wide variation in numbers. Many other observers have come to similar conclusions.

Professor Sedgwick and his assistants in an extended investigation of the ice supplies of Massachusetts (see *Report of the Massachusetts State Board of Health* for 1889) found in the natural ice of that state (which is mostly obtained from ponds, lakes, and rivers) very few living bacteria in the clear ice of the upper layers, but considerable numbers in some cases in the lower layers and in

the "bubbly" or "snow" ice. An examination of the artificial ice made in Massachusetts in 1892 proved the number of bacteria to be "insignificant under the prevailing methods of manufacture." *

It appears to be certain, therefore, that cold, even when extreme, cannot be depended on to kill all bacteria whether pathogenic or saprophytic; and both natural and artificial ice may, and generally do, contain more or less living microörganisms.

The pollution of ice. — Although from what has now been said it is clear that there is much truth in the popular opinion that water purifies itself in freezing, it is equally plain that too much reliance must not be placed upon this process. Ice should be made only from good raw materials, *i.e.*, from waters which are pure and potable; and this is doubly true if "artificial" rather than "natural" ice is to be used for public or private supplies. The processes of harvesting natural ice, and of delivering it to the consumer, still leave much to be desired. The use of horses whose droppings fall on the ice during the "plowing" or cutting of the ice fields; the uncleanly habits of the workmen employed; the floating of the blocks through less pure, or actually polluted water, on their way to the ice-house; their storage, often in a packing of old and dirty hay or sawdust; and their final delivery into family, club, or hotel refrigerators by common workmen after only hasty brushing with some ancient cloth or broom — these conditions illustrate the need of improvement.

The introduction and extensive use of electrical refrigeration for industrial and domestic purposes, is rapidly eliminating the undesirable features associated with the harvesting and delivery of natural ice. Ice for tea, coffee, and other beverages is now made in the home wherever electrical refrigeration or refrigeration by gas is available. Such ice is made from the regular drinking water supply, which happily in the great majority of cities is perfectly safe. In consequence the ice used is also safe. In addition it is free from those extraneous and objectionable pollutions to which all natural ice seems subject even at the present time.

Where artificial ice is produced on a large scale great care is usually exercised to employ only pure water. Hard waters are invariably softened, and waters which are suspected of containing

* T. M. Drown, *Twenty-fourth Annual Report State Board of Health of Massachusetts* (for 1892), p. 598.

undesirable bacteria are disinfected with chlorine. In addition as the water freezes, most of the foreign bodies present, including the bacteria, are concentrated toward the center of the metallic form in which the freezing takes place. Before the water is actually frozen, therefore, it is customary to remove these concentrated impurities by aspiration through clean rubber tubing which is inserted temporarily. In this way the manufacture of artificial ice is further protected against undesirable impurities.

With the recognition that ice may be a vehicle of disease, and that the bacteria present in ice are derived in part from the water whence it came, and in part from the contaminations resulting in handling and storage, efforts have been made by public health authorities to prevent the spread of disease in this way on common carriers. Accordingly, on trains and boats, a separate compartment is provided for storing ice used to refrigerate the drinking water from that employed for the water itself. Patrons are thus provided with iced or cooled water rather than with ice water.

Furthermore, great precautions are taken to prevent the contamination of ice on common carriers regardless of the use to which it is put. Ice is used not only to cool the drinking water in day coaches and Pullman cars, but it is likewise employed in a variety of ways in dining cars. Accordingly all ice taken aboard a train today is first cleansed in pure, running water, then transported in small, clean hard rubber trucks, and those engaged in handling the ice are required to wear clean rubber gloves. By observing these precautions the dangers inherent in ice are minimized. Not only is cooled water provided on all common carriers, but the health authorities supervise the safety of such waters, and in addition require that individual paper cups should be provided free, so that the patrons may obtain pure water properly cooled and use it with safety.

Through the development of mechanical refrigeration the ordinary water cooler hitherto so often observed in offices and other places of employment is giving way to the mechanically refrigerated cooler. Entire buildings, like hotels, are in fact so equipped today that mechanically refrigerated water is available on each floor and occasionally in each room. With the further extension of mechanical refrigeration the dangers hitherto associated with the use of natural ice will be eliminated almost entirely.

CHAPTER XII

THE SANITATION OF SWIMMING POOLS

Growth in number and use of swimming pools. — One of the noteworthy sanitary developments in the United States since the beginning of the twentieth century has been the increase in the number of swimming pools. In 1900 it is estimated that there were only 67 swimming pools in the United States; in 1913 this number had increased to 540, and at the end of 1929 the number exceeded 5,000. In New Jersey, at the end of 1929, there were approximately 75 indoor pools and 60 outdoor swimming pools. Since 1900 swimming pools have been constructed in conjunction with colleges, gymnasia, schools, hotels, steamships, country clubs, university and athletic clubs, as well as in parks, playgrounds, and recreation centers. The statistics alone indicate their rapid rise in popularity, and the extent to which hotels, steamships, and clubs have advertised their pools is further evidence of the popular appeal which they make.

Swimming, a popular form of exercise and recreation. — There is no doubt that swimming is one of the most delightful forms of exercise available to man. It is vigorous, cleansing, and refreshing. It is a delight especially during warm weather, for it is the only form of exercise which does not result in overheating the body or in producing perspiration. Furthermore, the contact between the skin and the water is exceedingly desirable from a hygienic standpoint, helping to improve circulation and serving as a beneficial influence in other ways.

It is not surprising, therefore, that swimming has become a popular form of recreation and exercise. In addition, the incentive to learn how to swim has been publicly stimulated in order to diminish the rapidly mounting deaths due to accidental drowning. In view of these conditions it is likely that the swimming pool is here to stay, and while it must always be regarded to some extent as a common bathtub, with all the accompanying health hazards, it must be admitted that sanitarians and public health officials can regulate and supervise such bathing places so that the danger to

health will be minimized, if not eliminated. Such regulation and supervision are particularly appropriate and necessary if swimming pools are to be built at public expense and children are to be required to use them as part of their school training.

Swimming pool, a potential vehicle of disease. — That the swimming pool is a potential vehicle of disease is a fact acknowledged by all sanitarians, and there is little doubt, furthermore, that swimming pools have been responsible for the transmission of disease. Since large numbers of people use a limited volume of water for bathing purposes simultaneously, and each individual expectorates or discharges water from the nose and mouth or pollutes the water in other ways, it is evident that the use of a swimming pool is always associated with some sanitary hazard. The innumerable laboratory investigations of swimming pool waters, and the sanitary inspections of swimming pools, confirm the existence of these potential dangers to health. In fact, in 1916, Professor Sedgwick advised an exclusive country club in Chicago not to accept a proposed gift of $100,000 for an outdoor swimming pool on hygienic grounds alone. But since it is impossible and perhaps even undesirable to prevent the growth and popularity of swimming pools the sanitarian must make them as free of danger as possible. At any rate this is now the prevailing point of view.

Although the relationship of swimming pools to the transmission of disease has long been suspected it has not been subject to such ready proof as is available where drinking waters are involved, nor is the danger of contracting intestinal disease as great. Although bathers may take water into their mouths, and may actually swallow an occasional mouthful, the amount so consumed is doubtless infinitesimal. Again, the water of a swimming pool is rarely, if ever, contaminated by the fecal discharges of the bathers, and while urinary contamination may occur more frequently, it probably does not represent a serious source of contamination. Therefore, if the water in the pool is safe when first introduced, there is little likelihood that it will become infected with pathogenic intestinal bacteria during the course of its use. Intestinal infections have occurred through the use of polluted waters for bathing purposes, but the possibility of obtaining such infection from some other bather during the common use of a swimming pool is rather remote.

On the other hand the opportunities for oral and respiratory

infections seem to be very much greater, for the water of the swimming pool enters the mouth, nose, ears, and eyes, and thus may prove to be a vehicle of disease through these portals of entry into the body. Diseases that have been especially associated with the use of swimming pools in recent years are rhinitis, tonsillitis, conjunctivitis, sinus infections, the common cold, and other respiratory infections.

Skin diseases represent another group of infections that may be transmitted through the common use of bathing beaches, dressing rooms, shower rooms, and swimming pools. Outstanding in this connection in 1934 was "athlete's foot" or ringworm, a very widespread skin disease affecting the feet, the hands, or any other part of the body, and often very difficult to eradicate once it has become established. Technically, the disease is often referred to as tinea, epidermophytosis, trichophyton, dermatophytosis, and blastomycoides. The responsible agent is a microorganism belonging to the yeast family. In some instances bathers have been required to immerse their feet in a pan containing a solution of sodium hypochlorite before entering and on leaving the pool. In other instances the floors of the dressing room and shower room have been mopped at comparatively frequent intervals with a solution of mercuric chloride. A 15 per cent solution of sodium thiosulphate has also been used as a foot bath. Immersion of the feet for 1 minute in such a solution or in a 0.5 per cent solution of sodium hypochlorite will destroy the microorganisms of ringworm that are present superficially on the skin. It is also desirable to cover all runways, springboards, mats, foot baths, and other surfaces used in common, with an effective chemical agent against the microorganism responsible for this disease, if effective preventive measures are to be employed. Protection may be obtained, however, through the use of bathing slippers.

There is also a possibility that the venereal diseases may be transmitted through swimming pools, primarily through the common use of infected and unsterilized towels and bathing suits. Since such practices are usually prohibited and since towels and bathing suits are used in common only after washing and sterilization, the danger of obtaining venereal infection in this way is slight.

Methods of safeguarding the swimming pool against its inherent sanitary deficiencies. — The protection of bathers against the possible dangers inherent in the use of swimming pools depends

on three factors: the design and construction of the pool, the dressing room, shower baths, and other necessary appurtenances; the effectiveness of the methods employed in purifying the water, together with the supervision maintained over the cleanliness of the pool, the shower rooms, and dressing rooms; and finally, the effectiveness of the supervision of the bathers themselves. It is essential, of course, that the water available for use in the pool should be of excellent quality, comparable in physical appearance and bacterial safety to the water used for drinking purposes.

Most pools today are operated on the continuous flow plan, the used water being removed from the pool constantly, and fresh water being introduced in the same amounts. In addition because of the expense involved in replacing used water with fresh, heated water, most pools are provided with a recirculating system and devices for purifying the water by rapid filtration in closed pressure filters and by chlorination. The plan of operating swimming pools on the fill and draw basis is not conducive to the maintenance of the highest sanitary quality, and accordingly this type of pool is not used extensively today.

Every pool ought to be so constructed that all entrances and exits should be located at the shallow end. In addition the construction should be such that all people using the pool should be required to enter the dressing room first, and then the showers and toilet rooms before entering the pool itself. Sanitary drinking fountains should also be available in the dressing rooms.

The pool should preferably be rectangular in shape, at least 60 feet in length, and the width should be a multiple of 5 feet. The surfaces should be smooth and easily cleaned, and should be made of water-proof material. The minimum depth at the deep end should be not less than 6 feet, and the area of the pool where the water is 5 feet deep or less should be at least 80 per cent of the total area of the pool. The slope of the bottom of the pool where the water is less than 6 feet in depth should not be more than 1 foot in each 15 feet. The depth of the water at the deepest end and at the 5-foot mark should be marked conspicuously on both sides of the pool, and markings showing variations in depth by one foot amounts are likewise desirable. All corners in the pool should be rounded, and the side and end walls should be vertical. The size of the pool should be determined by the maximum number of bathers permitted to use it at one time; and at the period of maxi-

mum use, each bather should be provided with an average of 27 square feet.

Every pool should be provided with an outlet at the deepest portion which will permit the pool to be emptied completely within 4 hours. In addition every pool of sufficient size should be provided with multiple inlets and outlets, the inlets being located about one foot below the water line. The outlets should be capable of draining to the sewers directly or to the recirculating pumps as desired.

Every pool must be provided with scum gutters, extending around the pool, and so constructed that sudden surges of water into them will not be washed out again into the pool. The scum gutter should be provided with drainage outlets about 10 feet apart, which should discharge into the sewers directly. All scum gutters should also be recessed into the walls of the pool in order to avoid any possible injury to bathers. Every pool should also have stairs, ladders, and step holes provided with hand rails, and these should be vertical or recessed in the pool walls.

The runway, surrounding the pool, should not be less than 4 feet in width. It should be made of non-slip material, should be smooth and easily cleaned, and should slope away from the pool at the rate of 0.25 inch to the foot.

The visitors' gallery should have separate entrances and exits from those used for the pool and should not overhang any portion of the pool surface. The floor should be made of impervious material, should have a drain, and should slope away from the pool.

The dressing rooms should be adequately ventilated and provided with satisfactory natural and artificial illumination. The walls should be smooth and made of impervious material, and the floor should likewise be impervious and have a drain. The lockers should be vermin proof, properly ventilated, and elevated above the floor at least 4 inches.

Hot and cold water showers should be provided to the extent of 1 for every 40 bathers expected at the time of the maximum use of the pool. Satisfactory toilet facilities should also be provided, one toilet for every 40 women, and one toilet and one urinal for every 60 men. Lavatories should be provided in the toilet rooms in the ratio of 1 bowl for every 60 bathers using the pool at the time of maximum load.

In order to insure satisfactory natural lighting in the pool,

available windows and skylights should have one-half the area of the pool, including the runways. Provision for satisfactory artificial lighting must also be made. In addition all indoor pools, dressing rooms, showers, and toilets must be heated as well as ventilated, and the temperature should be maintained between 70° and 75° F. The temperature of the water in the pool should not be elevated above 72° F., and the temperature of the air should not be permitted to rise more than 5° F. above the temperature of the water, nor fall more than 2° F. below it.

The equipment of the pool required to maintain the water in a satisfactory condition should consist of a hair catcher and suction cleaner in addition to the recirculating system, the pressure filters, and chlorinator. All visible sediment and scum should not be allowed to remain in the pool for a period longer than 24 hours, and the water must be maintained in a satisfactory physical and bacterial condition at all times. To this end the local health department should maintain adequate supervision by means of laboratory tests and sanitary inspections conducted at sufficiently frequent intervals. In order to insure the satisfactory operation of the pool trained and intelligent personnel must be provided. One or more adult attendants should be present constantly while the pool is in use, and facilities must be available for rescue work, for resuscitating an individual suffering from drowning, and for the treatment of injuries.

One of the essential elements in the control of infections through the use of swimming pools is the careful supervision of all bathers. Persons with colds, boils, skin eruptions, inflamed eyes, running ears, or any other obvious infection should be refused admittance to the pool. Similarly, anybody who is obviously unclean, or who has not taken a satisfactory preliminary shower bath should likewise be excluded. The shower bath should be taken with all clothing removed, and the use of soap should be compulsory. Absolute cleanliness of the perineal region is important. Every bather should be inspected by a responsible person for cleanliness and for the absence of obvious symptoms of disease and skin infections before being allowed to enter the pool. Bathers should also be required to empty the bladder before entering the pool, and to use the scum gutters for spitting. Spitting or blowing the nose in the pool must be prohibited, and this regulation should be rigidly enforced.

For indoor pools, nude bathing should be required. Where bath

ing suits are permitted, they should be simple in design, and made of undyed wool or cotton. All bathing suits should have fast colors. When bathing caps are employed, they should be made of rubber.

Suits and towels should preferably be provided by the management, and in such cases, should be washed with soap and boiling water after each using. Where they are the private property of the bathers, they should be thoroughly rinsed or washed each time they are used, and kept clean.

The proper care of a swimming pool requires intelligent and trained supervision, without which even the best designed and equipped plant will prove faulty. In spite of the lengthy recital of the detailed requirements for the satisfactory conduct of a swimming pool, there are many others which have not been included which depend primarily on the efficiency and training of the supervisor. With expert care in the conduct of the pool, with satisfactory construction and equipment, with adequate supervision of bathers, and with technical supervision by the local health department, it is believed that the sanitary dangers inherent in the use of public swimming pools can be largely eliminated.

CHAPTER XIII

THE SANITATION OF SUMMER CAMPS

Sanitary problems created by easy and universal travel. — With the development of the automobile and its almost universal ownership in the United States, together with the extensive construction of fine roads, areas once remote and inaccessible have been brought within comparatively easy reach of large numbers of people. To cross the United States by automobile is now a common occurrence, and no place is free any longer from possible human habitation, even though it be only of short duration. The essential needs of life, however, accompany man wherever he goes, and the sanitary precautions necessary to safeguard his own health and that of others, are often even greater in remote places than in the city. Accordingly state and local health departments have become acutely conscious of the necessity of providing sanitary facilities for the tourist and camper.

Camping, a gigantic problem today. — In order to accommodate these itinerant travelers, overnight or tourist camps have been established and operated for commercial profit, municipal tourist camps have been opened, camping grounds have been reserved for the use of tourists, and various other facilities have been provided. The problem has been increased greatly by the establishment of numerous summer camps for children and adults, camps operated by the Boy Scouts, the Girl Scouts, the Y.M.C.A., the Y.W.C.A., the Salvation Army, various tuberculosis associations and other health and welfare organizations, and the many camps operated for healthy children for commercial profit. In 1930 the State Health Department of Massachusetts surveyed 163 camps in Massachusetts alone. Of this number, 68, or 42 per cent, were privately owned, and 95, or 58 per cent, were conducted by various organizations of the type mentioned above. In fact "camping" is considered one of the major industries in Massachusetts today. Those who are familiar with the myriad camps that dot the lakes and hills and country regions of Maine, New Hampshire, and Vermont will appreciate that "camping" is also a major industry

in those New England states as well. This condition is duplicated in every part of the United States, so that the sanitation of camps has become an important public health administrative problem.

Sanitary problems of the gasoline filling station. — The great number of gasoline filling stations along the gigantic network of roads that connect every city, town, and hamlet also presents a major sanitary problem, for many of these provide drinking and toilet facilities, and it is important that both should be free of all health hazards. Various state health departments have certified to the safety of such facilities, following careful inspections, and where this is done the tourist and the community in general may feel amply protected.

Requirements for the safety and comfort of camps. — The requirements for the safety of all camps and for the health of the occupants are essentially the same, so that they may be considered simultaneously regardless of their nature. In certain types, especially those devoted to the care of children and the promotion of their health, special provision should be made for medical supervision, for the prevention of epidemic communicable diseases, and for wholesome and balanced nutrition as well as for sanitation.

In the selection of a camp site attention must be given to certain factors that do not have a direct relationship to health, but which are very important because of their indirect effect. Perhaps most important of all is the question of accessibility. A camp that is accessible may obtain conveniently the food and other accessories essential for health and comfort. In case of emergency medical aid may also be obtained readily. Such considerations must be taken into account in planning for the location of a camp, as well as in deciding whether one should stay at a certain camp in preference to another.

Another factor to consider is the question of soil drainage. A porous soil, preferably on the side of a hill, provides ample opportunity for drainage and for avoiding mosquito breeding places. It is also often of assistance in obtaining satisfactory water and sewerage facilities.

Having decided on a camp site with these precautions in mind, the next essential is to provide the necessary requirements for satisfactory sanitation. These include a safe and adequate water supply, the proper collection and disposal of sewage, the sanitary disposal of garbage and other organic wastes including rubbish, a

safe milk supply, proper protection and refrigeration of all foods, the elimination of flies and mosquitoes as well as adequate protection against them by screening, the avoidance of overcrowding, and the protection of the resident campers against injury or accident.

The water supply must be safe and adequate. Where a good city water supply is available this should be given preference. Where it is not available the water must be obtained either from wells or springs, or from mountain streams, lakes, or other acceptable sources. The essential requirement is that the water should be safe. In order to insure this condition camp owners should seek the expert advice of their state department of health or of recognized public health engineers. The layman is unable to decide such an important question for himself without the engineering and laboratory aids which those who are technically trained can employ. Every camp should, if possible, have running water. Its convenience is immeasurable, and its aid to safety is likewise great. Where water is derived from a well, it should be located on higher ground than the method of sewage disposal employed, and should be at least 100 feet away from any privy.

The disposal of sewage in a satisfactory manner is likewise essential. Where a town sewerage system is available, and running water is also at hand, the camp should utilize these facilities. In the absence of a sewerage system, recourse must be had to one of several satisfactory methods now available for disposing of human excrement in a safe and satisfactory manner. In such cases, the sewage should be disposed of in ground at a lower elevation than that from which the water supply is obtained. For small camps pit privies properly constructed and amply protected against flies and domestic animals may prove to be the cheapest satisfactory method of excreta disposal. In such cases the various precautions enumerated in the section dealing with excreta disposal should be strictly followed. Where the pit privy is not employed the chemical closet may be used, or recourse may be had to the septic tank or cesspool. The septic tank and cesspool make it possible to use flush toilets, and this is a great convenience. The requirements for a septic tank have already been outlined in the section dealing with excreta disposal, but as the construction of a cesspool has not been discussed, its essentials will be mentioned here.

A cesspool is usually built of field stone laid without mortar to within two feet of the surface, above which point the stone is laid in cement, curbed over, and provided with a cover. A cesspool should always be built in porous soil. The sewage discharged into a cesspool gradually leaches out into the surrounding soil, and is purified by oxidation. The resulting liquid eventually becomes part of the ground water supply. Wherever cesspools or septic tanks are employed, it is always desirable to provide a grease trap for the kitchen wastes particularly, since grease does not undergo decomposition very readily, and if present, would rise to the surface and curtail the period of anaërobic decomposition which the sewage itself should undergo. The grease trap should be adequate in capacity, at least 7 or 8 gallons, and should be cleaned out periodically as the local situation demands.

Garbage and other organic wastes must also be disposed of satisfactorily in order to eliminate nuisances and the potential menace to health through the agency of flies and rodents. Garbage should be kept in metal containers which should be covered constantly except during filling and emptying. Where the amount of garbage is large it may be necessary to remove it daily. In other instances removal two or three times a week should prove adequate. Garbage may be disposed of satisfactorily by allowing farmers to remove it frequently for feeding to hogs, or by burning or burial. Where the garbage is burned precautions should be taken to incinerate it completely and to avoid nuisances due to odors. Where garbage is disposed of by burial the trench must be 2 or 3 feet in depth, and the garbage should be covered with about 6 inches of soil. Rubbish can be disposed of satisfactorily by burning. Where fire is used either for destroying garbage or rubbish, care must be taken not to endanger the camp.

The milk supply should come from clean, healthy cows free from tuberculosis; it should be obtained by healthy milkers, and handled in sterile containers; it should be cooled promptly and kept cold; and it should be properly pasteurized before using. Raw milk must always be considered potentially dangerous.

The other foods used in camp must also be clean, fresh, and wholesome, and should be obtained from reliable sources or dealers. Adequate provision for satisfactory refrigeration should also be made. The kitchen and dining room should be thoroughly screened against flies, and other necessary measures for combating them

should be taken if thorough screening proves ineffective. The cook and other food handlers should be free of disease and care should be taken to eliminate any typhoid or diphtheria carriers among them. There should also be a generous supply of hot water, so that all dishes and eating utensils may be properly cleaned and sterilized. All food should be stored in such a manner that access to it by flies and rodents will be impossible.

Precautions must also be taken against flies and mosquitoes. By screening, by adequate protection of the food, by storing the garbage in covered metal containers, and by using satisfactory methods of sewage or excreta disposal, the fly nuisance can be reduced to a minimum. If mosquitoes are very prevalent little can be done to eliminate their breeding places by the campers or the camp owner, as to do so requires a considerable outlay of money. Camps should be located, however, in areas as free as possible from mosquito breeding places. To have mosquitoes present is not only exceedingly annoying, but in malarial districts or in areas where the anopheles mosquito is prevalent, they may be a menace to health. As much as possible should be done to control local mosquito nuisances by oiling and by preventing the accumulation of stagnant water. In addition proper screening material of sufficiently fine mesh must be used in all living quarters in order to obtain the maximum comfort and protection. In tent camps, where screening is impossible, mosquito netting should be used over each bed. Camps infested with bedbugs or cockroaches should not be permitted to operate until this objectionable condition has been eliminated.

All living quarters in use at a camp, including dormitories, dining rooms, kitchens, laundries, and other shelters should be rain proof and elevated above the ground, preferably 2 feet or more, in order to promote dryness and comfort.

Those camps devoted exclusively to the care of children, either healthy, pre-tuberculous, or those described as qualified for preventorium care, must in addition to the essential sanitary requirements outlined above, give attention to certain hygienic procedures, in order to prevent the spread of communicable disease and to build up the health of the children. Before a child is admitted to such a camp he should have been successfully vaccinated against smallpox and immunized against diphtheria. Every child must also have a complete physical examination before admission.

Serious physical defects such as enlarged and diseased tonsils and adenoids, dental caries, and defective vision, should be corrected preferably before the child is admitted to camp. Children suffering from any skin disease or with any of the symptoms of communicable disease, should not be admitted. During the first two weeks following the opening of the camp all visitors should be excluded. Every child should be carefully observed daily for the early symptoms of disease, and a daily afternoon temperature reading should be made during this period at least. Children showing a rise in temperature equal to 0.5° F. should be isolated immediately and kept in bed until the temperature is normal for at least 24 hours. If the child develops a communicable disease medical and nursing attention must be provided and the necessary measures essential to prevent an epidemic must be taken promptly. Children who are admitted late must be subject to the above precautionary measures for a period of two weeks.

After the two weeks period of isolation is over visiting at camps operated by public or private health agencies, or by charitable or welfare agencies, should be limited to Sundays only. In this way the regular routine of the children will be least disturbed, the likelihood of introducing disease from the outside will be greatly diminished, and the mental health of the children will be fostered. Visiting on the part of children should also be discouraged.

The food served at the camp should be clean, wholesome, and safe, and the diet should be such as to promote health, growth, and proper elimination. This means in addition to the use of a clean, pasteurized milk, sufficient green vegetables, fruits, and whole grain cereals in the form of cereal and bread, as well as butterfat, carbohydrates, like potato, and proteins such as meat, fish, and eggs. The fruits should include oranges, but if these are too expensive to serve, then tomatoes or tomato juice may be substituted. A balanced diet with emphasis on mineral salts and vitamins is essential for health and growth.

Intimately associated with nutrition is the important factor of rest. Children in camps often have altogether too much exercise. This should be especially avoided where the children are physically below par. In such cases the daily schedule should be so arranged that rest in bed for a period of 1.5 hours after the midday meal is required, and a brief rest period of 30 minutes before dinner may also be desirable.

Cleanliness is likewise important. Each child should be required to wash its hands and face before each meal, and the hands should be thoroughly washed each time after using the toilet. Teeth should be brushed, preferably in running water, before breakfast and before retiring at night. A thorough, cleansing, all-over bath should be required once a week, and this should include the washing of the hair. The daily care of finger nails should likewise be made compulsory.

Wholesome exercise is essential for robust health and for the proper assimilation of food. Excessive exercise is, however, undesirable, and in the case of children who are physically below par, may even be injurious. It is therefore wise to prescribe the physical activities in which each child may indulge, in accord with its specific needs. This should be done by a competent physician and should not be left to the physical instructors. Provision should also be made for the safety of the children while they are bathing or boating, and against any other hazard which a local situation may present.

The opportunity for health education in camp groups should not be overlooked, especially in those camps designed for pretuberculous children, for preventorium children, and for others whose health is impaired. By adequate correlation with the normal activities of the camp instruction can be given on the requirements of an adequate and satisfactory diet, on the importance of cleanliness and oral hygiene, and on the significance of rest, bowel hygiene, sunlight, sleep, and other recuperative and health promoting habits. Camp life should be a demonstration of the essentials of healthy, decent living, both physical and mental, and there should be sufficient emphasis on proper deportment at table, in assemblies, and in smaller groups in order to build up a proper respect for social relations. In some instances this sort of health and social instruction must be carried into the home in order to enlist the cooperation of the parents, and to insure the effectiveness of the effort made in camp.

Where special health camps are conducted it is also desirable to give each child a physical examination before leaving camp in order to ascertain the physical progress which the child has made and to detect any incipient condition of disease which should be reported to the health authorities. Wherever possible a physician should be in daily attendance or within easy reach but a nurse

should be on hand all the time. Provision should also be made for isolating and hospitalizing children whenever necessary, or for transportation to a registered hospital where local facilities are not adequate for satisfactory treatment. A camp must also have on hand a fully equipped first aid chest, and some one competent to administer the prone-pressure method of resuscitation in case the need should arise.

CHAPTER XIV

MILK SUPPLIES AND THE PUBLIC HEALTH

Milk, an ideal food, also an important, potential vehicle of disease. — Of all the foods available to man probably none is of such great importance as milk. Milk, if fresh and clean, has been described as the most nearly perfect food. Its very excellence as a food, and its extensive use, especially for children, make it necessary for sanitarians to exhibit an unusual interest in its quality — partly because of its value in human nutrition, but equally, because of its intimate relationship to the public health. For among all the vehicles of disease there is perhaps none more *potentially* dangerous to man than infected milk. This fact, based upon the scientific discoveries in bacteriology during the past forty years, is one of the outstanding sanitary conclusions established during this period. Nevertheless, even today, this important relationship between dirty and contaminated milk and possible disease is not recognized as universally as should be the case. Perhaps this is in part because milk has always been one of the most trusted of human foods. Of high repute for easy digestibility; believed to represent in perfection a natural dietary; in general, popular and cheap — milk has always deservedly held a high place in the public esteem. On the other hand, as informed physicians and sanitarians will testify, the use of raw milk has been associated altogether too frequently with diseases of epidemic type, and in spite of its excellent reputation as a cheap and valuable food, increasing attention has been directed toward the problem of making milk a safe food for human consumption.

While the value of milk as a source of human food has been appreciated from time immemorial, the impetus to use this food abundantly in the daily diet is largely the result of the extensive campaigns of popular education that followed in the wake of the remarkable discoveries concerning the requirements of an adequate and satisfactory diet. It was emphatically claimed that milk is not merely a food for babes. Mothers, school children, and even male adults were urged to introduce liberal amounts of

milk in the daily diet, especially in order to insure an adequacy of such important nutritional elements as the vitamins and mineral salts.

Obviously, if people are to be urged to use milk liberally in the diet, it is important that the milk itself should be absolutely safe for human consumption. This fact was early apparent to those who had studied the problems of city milk supplies. It was more widely recognized when the nation-wide study made by the American Child Health Association in 1923 demonstrated that the milk supplies available in many cities and towns of the United States were not safe for human consumption. A campaign was undertaken by that organization in cooperation with the Conference of State and Provincial Health Authorities and the Association of Dairy, Food, and Drug Officials to inaugurate "a nation-wide movement to secure for every baby, child and adult in America a clean and safe milk supply." By 1930 twenty-nine of the states and one province of Canada had been carefully surveyed. These studies demonstrated quite definitely the need of further work to reduce the dangers from microbic infection and to improve the sanitary quality of the milk supplied throughout the country. During recent years much progress has been made, partly through inspection and education, but largely through the gradual introduction of pasteurization. It is possible therefore to foresee the time when the consumption of milk in this country will be as safe as is the consumption of water in most of our larger municipalities.

Milk consumption. — Milk has been defined as the nutritive secretion of the mammary gland. As long as the infant obtained its milk directly from its mother's breast, its nourishment was practically devoid of hazards. But today most infants are not breast fed for an extended period. Thus cow's milk has been introduced into the daily dietary of infants and growing children, of invalids, and of many adults in perfect health. Goat's milk may also be so employed, but in the United States the amount of goat's milk used for human consumption is comparatively small. We are therefore confronted primarily with the problem of insuring the safety and wholesomeness of cow's milk. In the United States there are nearly 25,000,000 dairy cows from which the amount of milk produced annually is in excess of 125,000,000,000 pounds. Since this milk is produced on farms where the sanitary

practices vary considerably, it is evident that the problem of supervising the sanitary production of milk is one of great magnitude.

In 1926, the per capita consumption of fluid milk in the United States was 55.3 gallons per year, an amount slightly in excess of one pint per capita per day. It is of interest to note that in the same year there were only four nations in Europe that exceeded the United States in the per capita amount of milk consumed. They were Finland, with a consumption of 83.9 gallons, Switzerland, with a consumption of 70.4 gallons, Sweden, with a consumption of 69.7 gallons, and Norway, with a consumption of 56.0 gallons. Since the per capita milk consumption in other parts of the world, with the possible exception of New Zealand, is relatively small, it is obvious that the United States ranks among the leaders of the world in per capita milk consumption. It is noteworthy that those nations which consume milk and dairy products in abundance enjoy a dietary which favors complete and adequate nutrition; and this essential requirement must be met if humans are to enjoy good health and if they are to possess the vitality necessary for material and mental achievements.

Milk producing areas in the United States. — In the United States the great milk producing area extends from New England and the middle Atlantic states westward to the northern states of the Mississippi River valley. A second dairy area comprises sections of California, Oregon, and Washington. Although dairying has not been introduced extensively in the south and southwestern portions of the United States it is developing even in these less urban regions.

Composition of milk. — The food value of milk makes it desirable to inquire carefully into its composition. Although it consists very largely of water, it also contains proteins, carbohydrates, and fat — foods which are essential for the replacement of the used-up protoplasm of the body and for supplying its energy needs. In addition milk also contains mineral salts and some of the vitamins which play a very significant rôle in promoting the health and general well-being of the individual. Fresh milk is also known to contain small quantities of various gases in solution, and also certain enzymes. It is doubtful whether the gases in solution have any personal or public health significance and our knowledge of the value of the enzymes in milk is not sufficiently developed at

present to enable us to conclude that their presence is of importance to man. Milk also contains various types of cells, such as epithelial and blood cells, the significance of which will be described later.

Numerous analyses of normal milks obtained in various parts of the United States show that milk contains between 87.1 and 87.5 per cent water. The butterfat content of milk may vary from less than 3 to more than 6 per cent, but usually approximates 4 per cent; the carbohydrate material, known as milk sugar or lactose, varies between 4.0 and 6.5 per cent, but is usually between 4.75 and 5.1 per cent; the protein in milk, which is composed of casein, lactalbumin, and lactglobulin, may vary between 3 and 5 per cent, and usually represents about 3.5 per cent of the milk. The ash in milk will vary between 0.7 and 0.8 per cent; the solids not fat vary between 7.6 and 9.5 per cent, and averages about 8.75 per cent; and the total solids will vary between 11.6 and 14.6 per cent, and average about 12.8 per cent. The following table shows the average composition of normal herd milks.

TABLE 11

TYPICAL ANALYSES OF NORMAL MILKS

(Values given in per cent)

AUTHOR	WATER	FAT	MILK SUGAR	CASEIN	ALBUMIN	ASH	SOLIDS NOT FAT	TOTAL SOLIDS	TOTAL
Van Slyke	87.1	3.9	5.10	2.5	0.7	0.70	9.0	12.9	100
Babcock	87.3	3.6	4.50	3.0	0.8	0.70	9.1	12.7	100

Nutritional aspects of milk. — Although the water content of milk is high, the solid ingredients are of such value and are present in such combinations and concentration that milk is an excellent if not quite ideal, food. Although containing protein, carbohydrate, fats, and some vitamins and certain mineral salts, it is lacking in a few desirable ingredients. For example, milk is not a good source of vitamin C, the anti-scorbutic vitamin, and what there is may soon be destroyed by oxidation. Hence, the necessity of supplementing the diets even of young infants with such materials as orange juice or tomato juice which are excellent sources of vitamin C.

Milk is also deficient in vitamin B, the anti-neuritic vitamin. Since the vitamin content of milk is dependent in part, at least, on the diet of the cow, the nutrition of the cow determines to some

degree the production of milk that is satisfactory from a nutritional point of view. Since the regulation of the cow's diet is beyond the influence of the average individual it is necessary to bear in mind that other foods are required to supplement the human dietary.

The most serious deficiency of milk is iron. Infants and young animals restricted to milk, or milk and other iron-poor foods for a considerable period, develop anemia. Nature has provided against this condition for infants by supplying the infant with a reserve supply of iron to tide over the early months of infancy until that time when its diet becomes more varied. The addition of boiled water to the infant's diet helps to make up the deficiency of iron in its milk supply. Since the iron in the body is used for the production of hemoglobin (the red pigment in the blood), and since hemoglobin is not formed unless there is also present a small amount of copper in the body, it is obvious that copper as well as iron is an important mineral constituent of the diet. Freshly drawn milk is also deficient in copper, although the amount present is often increased slightly after the milk is processed for consumption, due tô the copper that is taken up from the various utensils with which the milk comes in contact.

The importance of iodine in the diet has also been established by recent research in nutrition and the relationship between simple goiter and iodine deficiency has been demonstrated. Attempts have been made to overcome this lack in the human diet in certain areas of the United States by producing and offering for sale an iodized milk. This is accomplished by regulating the dietary of the cow and not by the direct introduction of iodine salts into the milk. It has been proposed to overcome the iron and copper deficiencies of freshly drawn milk in a similar manner.

We are thus likely to see extensive efforts made in this country to "improve" on the one natural food which already has a very high reputation as our nearest approach to a complete food. In fact, in their attempts to commercialize plausible half-truths and highly theoretical conclusions, a few producers and manufacturers who are quick to appreciate the publicity and possibly the monetary advantages of the discoveries of modern science are now offering iodized milk and milks containing iron and copper. Attempts are likewise being made to produce and market vitamin A milk, vitamin B-1 milk, vitamin D milk, and "soft curd" milk. Efforts

have also been made to discredit pasteurized milk in favor of raw milk on the basis that the calcium and phosphorus salts present in milk, so important in bone development and in the prevention of rickets, are assimilated more readily from raw milk. Fortunately this "observation" has been carefully studied in the field and laboratory, and has been found to be without basis. Of these proposed modifications the most practicable seems to be that in which the vitamin D content is increased.

There may be a distinct field of usefulness for milks with increased vitamin D content because the use of such milk provides a simple and easy way of introducing an adequate amount of the anti-rachitic vitamin in the dietary of infants and young children. This method of administering vitamin D would be especially desirable in those cases where the use of cod liver oil, viosterol, halibut oil, etc., is associated with difficulty or displeasure by the consumer.

Vitamin D milk may be made in one of several ways. A method commonly adopted by the certified milk producers in the United States is to incorporate a definite amount of activated (irradiated) dried yeast in the diet of the cow. The anti-rachitic potency of the milk as measured by biological assays on white rats must be not less than 160 Steenbock units per quart, equivalent to 4 teaspoonfuls of standard cod liver oil, or 10 drops of viosterol. A second method of producing vitamin D milk consists in adding a cod liver oil concentrate to the milk. This concentrate contains not less than 900,000 vitamin D units to the pound, and sufficient amounts are added to the milk under treatment with the aid of homogenization. A third method of preparing vitamin D milk consists in exposing a thin film of milk for a few seconds to the ultraviolet rays produced by a carbon arc lamp. Milk treated in this way and containing only 50 vitamin D units per quart as determined by the standard rat test has been found to be effective in protecting infants against rickets. No objectionable taste or flavor is imparted to the milk by direct irradiation, if the exposure is carefully controlled. Since all milk, whether specially treated or not, contains a certain amount of vitamin D, it is not surprising to learn that a fourth method of increasing the vitamin D content of milk consists of irradiating the cows directly. This method is not used, however, in the commercial production of vitamin D milk.

Considerable objection has developed in certain quarters con-

cerning the treatment of milk for the purpose of increasing its anti-rachitic potency, on the ground that such milk has had something added to it which the freshly drawn milk did not contain and hence must be classified as adulterated milk. While it is eminently desirable to prevent milk from becoming the vehicle of various food and health fads, it is absurd to take the position that only freshly drawn milk, untreated and untouched in any way, must be available for human consumption. It is obvious that such a stand, if carried to extremes, would prevent the usual sanitary procedures involved in clarification and straining of milk to remove hair, dirt, and other foreign matter. Such a point of view would be opposed to pasteurization, which admittedly has been the principal factor in promoting the safe consumption of milk in our urbanized areas. If milk is to hold its high place as a food for general consumption, processes for its treatment must be viewed with a sense of practicality as well as of scientific interest, and the intelligent handling, treatment, and modification of milk supplies as a process of food technology must come under the scope of sane and acceptable public health practice.

Not only is it possible to increase the vitamin D content of whole milk, but it is also feasible to activate powdered milk and evaporated milk. Since powdered milk and evaporated milk are used extensively in infant feeding both in urban centers as well as more isolated areas, the value of having such foods high in anti-rachitic potency, especially in regions where the significance of vitamin D is not fully appreciated, must be obvious.

Some agitation has also been observed in this country in favor of the production and sale of "soft curd milk." Such milk is reputed to be more readily digested by infants and children and hence is regarded as preferable to hard curd milk. Soft curd milk may be a natural product obtained from certain cows during a prescribed period of lactation, or it may be produced by subjecting the milk to prolonged heat treatment or to homogenization or to a combination of both. Its sphere of usefulness is primarily restricted to those infants and children who are under medical supervision, and for whom the use of soft curd milk has been prescribed. Therefore it is doubtful whether soft curd milk will be distributed commercially to any great extent.

Mention has been made of the fact that although raw milk always contains some vitamin C it can advantageously be sup-

plemented by orange juice or tomato juice. Furthermore this vitamin is easily affected by oxidation so that its concentration in milk is further diminished either by ageing or by pasteurization in an atmosphere of air or oxygen. Raw milk is also deficient in vitamin B, the anti-neuritic principle. On the other hand milk fat is a rich and excellent source of vitamin A, the growth promoting vitamin, which is not affected by heat up to boiling, but is capable of being destroyed by oxidation. From the foregoing it is evident that milk is low in vitamins except for vitamin A. In addition to small amounts of vitamins B, C, and D, it also contains small quantities of vitamin E, the so-called thermostable sex vitamin, and appreciable amounts of vitamin G, the pellagra preventive principle.

Milk proteins. — The proteins in milk are of exceptionally high quality. They can be resolved into the 18 amino acids essential for building up animal tissues. The milk proteins include casein, which represents about 80 per cent of all the protein, lactalbumin, 15 per cent, and lactglobulin, 5 per cent.

Milk carbohydrate. — The carbohydrate in milk is milk sugar or lactose. It contributes about 29 per cent of all the calories obtainable from milk. It is acted upon quite readily by bacteria and is the source of the lactic acid which brings about the souring of the milk.

Milk fat. — Milk fat, or butterfat, as it is more commonly called, is a very important ingredient in milk. The fats are present in milk in an emulsified condition. The fat globules rise readily to a well-defined cream layer as the milk is left undisturbed. When "ripened" and concentrated by churning the product is butter. The milk fats are also the most important ingredient of ice cream, a food of constantly growing importance. The fat portion of milk is not only of high energy value, but a rich source of vitamin A, and the vitamins D and E are also associated with it.

Mineral salts. — The mineral salts of milk consist largely of phosphates, chlorides, and sulphates, of calcium, sodium, potassium, and magnesium. Associated with these are small quantities of salts of organic acids, especially citrates. Milk is one of the most readily utilized sources of calcium and phosphorus, and these elements are particularly valuable in the building of bone tissue in the presence of vitamin D. The great significance of milk to the nutrition of infants and growing children is therefore apparent.

Milk enzymes. — Milk contains various enzymes including catalase, galactase, lactokinase, lipase, peroxidase, and reductase. Their function and value in the digestion of milk are practically unknown. Although they are readily inactivated by heat they can withstand temperatures between 140° and 149° F. for brief intervals. Therefore low temperature pasteurization does not seriously affect them. At 150° to 158° F., their activity is weakened considerably, and above 159° F., the enzymes are said to be inactivated completely.

Cellular content of milk. — Since milk is elaborated in special gland cells which rupture when their contents are discharged, fresh milk always contains numerous and varied cells derived from the body of the cow, and these may be observed on microscopic examination after suitable staining. Some of these are epithelial cells, derived from the glands, milk ducts, and milk cistern; others are erythrocytes or red blood cells, and still others are leucocytes or white blood cells, both of the mononuclear and polynuclear types. The presence of these various cells even in large numbers in most milks is of no public health significance. However, the presence of very large numbers of polynuclear leucocytes, accompanied by and associated with long-chain streptococci, indicates a streptococcic udder infection with practical certainty. Such milk is regarded as dangerous if used in the raw state. While thorough heating undoubtedly destroys the possibility of its infectiousness, milk showing such bacterial invasion should be eliminated from human consumption.

Color, reaction, and opacity of milk. — Milk is yellowish-white in color, and because of emulsified fat and colloidal protein, is opaque to the transmission of light. It has a sweet taste and a characteristic odor. It has an amphoteric reaction to litmus, is acid to phenolphthalein, and the pH varies between 6.5 and 7.20. In general the pH of freshly drawn milk is in excess of 6.76.

The yellow color of milk is largely due to carotin derived from the fat globules and is likely to be more intense in the summer when the cows are in the pasture. The opacity of milk free from cream is due to the colloidal suspension of the casein in the serum.

Other forms of milk. — Not only is whole milk used as a fresh product, but large quantities of milk are used in the commercial forms of condensed, evaporated, and powdered milks. Sweetened condensed milk is prepared from whole milk by evaporation at low

heat under a vacuum, with the addition of cane sugar. It contains in general about 42 per cent sugar and 27.4 per cent water. In 1928 approximately 159,000,000 cans of condensed milk were produced in the United States. Although the use of sweetened condensed milk is somewhat diminishing, the use of evaporated (canned) milk has rapidly increased. The annual production of evaporated milk in the United States varies between 800,000,000 and 1,200,000,000 cans. Powdered milks are also enjoying great popularity and many uses. The total production of all dried milk products in 1927 approximated 200,000,000 pounds. Most of this is powdered skim milk and only a small portion is powdered whole milk. Dried milks are often used when fresh whole milk is difficult to obtain, and are employed for infant feeding, for general household and culinary purposes, for bread making, and for the manufacture of confectionery and ice cream. Because of the efficiency of preparation and the heat treatment these products may be looked upon as foods of excellent sanitary quality.

Nearly 47 per cent of the milk produced in the United States is used as fluid milk or cream. The per capita consumption of milk in 1926 was 55.3 gallons; butter, 17.82 pounds; cheese, 4.36 pounds; condensed and evaporated milk, 14.32 pounds; and ice cream, 2.77 gallons.

Development of city milk supply problems. — Prior to 1840 very little milk was shipped by rail from the country to the cities. Practically all of it was brought to the city by the producer's wagon and delivered to his customers. The milk business was then a personal relationship between the producer and the consumer, a relationship which still exists in some of the smaller cities and towns in the United States. The purveying of milk in the large city, on the other hand, has become a great and highly organized business, with hundreds of millions of dollars invested, not only in farms, cows, and dairy equipment, but in special tank cars and trucks, in large installations for pasteurizing and other treatments, and in the necessary distribution facilities. The milkman of the past has become replaced by gigantic, industrial corporations, with stockholders and boards of directors, with personnel and field directors, publicity managers, public relations officials, laboratories for supervision and research, health education directors, and various other departments with specialized activities. All this is due to the rapid growth of our metropolitan districts which has extended to ever

greater distances the "milk-shed" area supplying each with milk. Milk is now shipped regularly to the larger cities not only from nearby areas but from districts over 300 miles away. To meet the modern requirements milk must be obtained fresh and relatively clean in the producing areas, and transported and delivered daily to the city resident without deterioration, after being rendered safe by pasteurization. Keeping always in mind the possibility that milk may be an important vehicle of disease, one readily understands the necessity for constant and effective supervision by trained representatives of the great companies and by city and state departments of health.

The attitude of the dairy farmer toward milk production has also undergone considerable modification. No longer is milk production of secondary or even minor importance; it is a primary branch of agriculture which, properly pursued, requires careful time adjustment, intelligent labor, and adequate attention to sanitary principles. As a result, it has the potentiality of returning to the farmer a satisfactory profit. His efforts to produce a clean, wholesome milk supply of low bacterial content have been stimulated in part by public health education, in part by farm inspections and laboratory examinations; but to a large extent by the increased compensation he can earn from the milk dealer because of the high butterfat content of his milk and its low bacterial content.

Formerly most milk was shipped to the city in cans of either 10 or 40 quarts capacity. The ten-quart cans, which were popular in New England, were provided with wooden plugs—an unsatisfactory sanitary arrangement. Sometimes the milks were iced in transit and sometimes they were not. Later, milk was shipped to the city in refrigerator cars or it was first cooled and pasteurized in the country, bottled, and then shipped to the city in such cars. More recently still milk has been cooled promptly to 40° F. or even lower at the point of production, and shipped at that temperature in specially constructed tank cars and tank trucks. Tank trucks are used for distances up to 60 or 75 miles from the city, while tank cars are employed for greater distances. When the milk arrives in the city it is either pumped or forced by compressed air through clean and sterile sealed pipes into the plant where the processing takes place, and thus is not exposed to the air nor subjected to contamination. When the tank car is empty it is thor-

oughly cleansed and sterilized and returned to the country for the next shipment of milk from that source.

As an illustration of the modern milk problem confronting the large city today the example of Detroit in 1932 may be cited. Milk produced for this city came from about 14,000 different farms located within an area west and north of the city having a radius of 125 miles. These farms are under the constant supervision of 15 country milk inspectors, and each farm is inspected and scored at least once each year. Ever since 1929 all the milk has been derived from tuberculin tested herds. The milk obtained on the farms is hauled to one of 75 country receiving stations, where it is cooled. Subsequently, practically all of it is shipped to the city in glass-lined, thermos-like tanks on trucks. After arriving at the city milk plant the milk is pasteurized, cooled, bottled, sealed, and delivered to the ultimate consumer. The sale of loose milk is forbidden by city ordinance. There are 42 pasteurizing plants in Detroit, each of which is inspected at least semi-weekly. The approved method of pasteurization consists of holding the milk at 142° to 145° F. for 30 minutes. Samples of milk are taken frequently both in the country and the city, and submitted to the regular laboratory examinations to determine their sanitary quality. In 1932, 99.9 per cent of the milk supply in Detroit was pasteurized, the only exception being one of the four farms producing certified milk. The daily consumption of fluid milk and cream was 0.92 pint per capita.

Milk in relation to disease. — It is only in comparatively recent times that milk supplies have been generally recognized as potential vehicles of disease. Yet, apparently the first evidence that disease may be spread by milk was presented by Dr. Michael Taylor of Penrith, England, in 1857. Although this was before the germ theory of disease was established scientifically, Dr. Taylor was able to demonstrate by careful epidemiological study that a case of typhoid fever occurring in a family that produced and sold milk to 14 other families in the same town, resulted in the infection of the milk and the transmission of the disease to the consumers. Again in 1867 Dr. Taylor demonstrated in a similar way that an epidemic of scarlet fever in Penrith originated through infection introduced into the milk supply in a cottage where a case of scarlet fever had occurred, and was spread through the medium of the infected milk to at least six other families using the same supply.

At about the same time Professor Oswald Bell investigated an outbreak of scarlet fever and arrived at the same conclusion. In 1877 an epidemic of diphtheria was traced to a milk supply. Records of these and other instances of the rôle of milk in the transmission of disease were brought together and presented by Mr. Ernest Hart at the International Medical Congress in 1881. The paper presented a record of 50 epidemics of typhoid fever, 15 epidemics of scarlet fever, and four epidemics of diphtheria which were charged to infected milk.

Although the evidence was beginning to accumulate that milk may be a dangerous vehicle of disease the information spread very slowly and doubtless many epidemics occurred of which no record exists. Besides, the remedy was somewhat in dispute. There were a few courageous individuals who recognized the dangers of drinking raw milk and who recommended the use of heated milk exclusively. Thus, Dr. Jacobi of New York, as early as 1873, recommended that all milk used for infant feeding should be put in feeding bottles and heated momentarily at 212° F. Soxhlet in Germany, in 1886, devised a small apparatus for sterilizing milk in the home, and Caille of New York recommended its adoption for preparing infant feedings in that city. In this he was supported by Dr. Jacobi. In 1893, Nathan Straus, a prominent New York business man and philanthropist, became convinced that the infant death rate could be greatly diminished through improving the quality of milk and through the use of pasteurized milk only. Accordingly he established the first milk depot in New York in 1893, and from June to November distributed 34,400 bottles of pasteurized, modified milk. The success of this demonstration in saving human life was so great that six stations were established in 1894, and 306,446 bottles of pasteurized milk were distributed. Later, in order to demonstrate further the value of pasteurization as a public health measure, Mr. Straus established stations in the parks of New York at which pasteurized milk was sold for only a penny a glass. In this trail-blazing work Mr. Straus was encouraged and supported by Professor Sedgwick in Boston, who was conducting an energetic campaign in New England in favor of the use of "cooked milk."

But progress was very slow. Physicians and learned men in large numbers were still opposed to the use of heated milk. In 1894, the distinguished German Professor of Hygiene, Dr. Flugge,

opposed the heating of milk on the ground that the organisms remaining in the milk after the heat treatment would cause putrefaction and the formation of toxins in the intestinal tract. Furthermore commercial pasteurization as attempted in these early days was far from being satisfactory. In theory high temperatures and short periods of exposure were employed, but there was no adequate temperature control and no assurance that all the milk was heated. While the keeping quality of the milk was improved, the destruction of all pathogenic bacteria was not always accomplished. Moreover, the opponents of pasteurization maintained that heated milk was not natural and lacked health giving and nutritious qualities. The adherents of pasteurization were, however, constantly at work on improving the process. Outbreaks of disease due to infected milk kept the matter before the scientific public. As a result pasteurization made great progress in America and by 1905 had gained undisputed recognition among health authorities. Lessons based on the experience of a generation or more, in field and laboratory, have attained general acceptance, but even at the present time opponents to pasteurization are unwilling to accept it as the most practicable solution of the problem of milk and disease.

An illustration in support of this unfortunate situation is found in the case of the Manchester (England) Corporation Bill which was defeated by popular vote.* The bill provided that all milk other than certified and Grade A, both of which were obtained from tuberculin tested cattle, should be pasteurized. Prior to the vote the City Council attempted to create a popular reaction in favor of the bill through an energetic educational campaign. Over 350,000 leaflets were distributed and it was brought out that 75 per cent of the city's milk supply was pasteurized already. The people were also informed that 323 children became infected with bovine tuberculosis annually, and that the treatment of these patients costs the city a total of $90,000 per year. It was also disclosed that in 1929, from 10.0 to 12.5 per cent of the milks coming into Manchester showed the presence of living tubercle bacilli; that 40 per cent of the herds in England react to the tuberculin test and that 2 per cent of the milch cows have tuberculosis of the udder. The defeat of this measure illustrates the futility of settling important scientific questions by a popular vote, and the duty

* Editorial, *Jour. A.P.H.A.*, v. XXIII, No. 5, May, 1933, p. 479.

which rests with all authorized health authorities to protect the public health effectively in spite of widespread ignorance, prejudice, and even opposition.

During 1905 to 1906 numerous laboratory investigations were conducted to determine the effect of heat on bacteria in milk. It was soon established that both the milk souring bacteria as well as the pathogenic bacteria were destroyed at temperatures much below 212° F., and gradually the holding method of pasteurizing milk began to replace the flash method. In 1906 Rosenau, studying the thermal death points of bacteria in milk, demonstrated that pathogenic bacteria in milk could be destroyed by heating the milk to 140° F. and holding it at that temperature for 20 minutes. In the same year North revived a suggestion made by Monrad, a Danish expert, in 1895, that milk can be properly pasteurized by holding it at a given temperature for 30 minutes; and in 1907 the first commercial pasteurizer, operating on the holding plan, was installed in New York. Milk was introduced into these pasteurizers at temperatures varying between 140° and 150° F. and kept at these temperatures for 30 to 45 minutes. The results were very satisfactory.

At the same time there was accumulating a mass of incontrovertible evidence to the effect that the use of pasteurized milk was saving human lives. In 1903 Park and Holt in New York fed two groups of tenement house babies on raw milk and on the same milk pasteurized. The babies on the pasteurized milk diet showed a strikingly lower mortality from infant diarrhea and other causes. This demonstration helped to establish the wisdom of using pasteurized milk for infant feeding.

Another classic demonstration of the value of pasteurized milk occurred in a children's institution on Randall's Island, N.Y. During the three-year period from 1895 to 1897, 1,509 children of a total of 3,609 under treatment, or 41.8 per cent, died of diarrheal diseases. Raw milk was in constant use during this period. Early in 1898 the use of pasteurized milk was substituted, and although there was no change in the hygienic surroundings or treatment of the children during the seven-year period from 1898 to 1904, out of a total of 6,200 children under treatment 1,349, or only 21.75 per cent succumbed to diarrheal diseases. Again, in the single month of August, 1908, there were over 300 more deaths in New York State from diarrhea in children than in the entire year of 1928. The same

graphic achievement of pasteurization as a life saving measure has been witnessed in every city and town where effective pasteurization of milk has been introduced.

Diseases spread through milk. — The diseases spread through milk and milk products may be divided into two groups according to the source of the infectious material. If the infectious material *comes from the animal directly*, the diseases that may be transmitted through milk are tuberculosis, Malta fever, contagious abortion (undulant fever), foot and mouth disease, Johne's disease, anthrax, actinomycosis, and milk sickness or trembles. The diseases of greatest significance to man in the above list are tuberculosis, Malta fever, and contagious abortion. There is still some doubt as to whether all udder infections arising in cows are necessarily of serious consequence to man. In cases where the infectious organism is the tubercle bacillus or the hemolytic streptococcus of septic sore throat, there is of course no question concerning the potential danger to humans. It is wise, therefore, to refrain from using milk derived from any animal showing an udder infection, even though some of these infections may not be capable of transmitting disease to man. The other diseases of animal origin, listed in the above group, are of minor significance as public health problems today.

Of much greater significance to the public health are the diseases transmitted through milk and milk products that have their origin in man. Among these diseases are those of intestinal origin such as typhoid fever, paratyphoid fever, cholera, dysentery and diarrhea, and infant diarrhea. In addition there are the respiratory diseases such as septic sore throat, scarlet fever, and diphtheria. In recent years evidence has been presented by one investigator particularly, which indicates that under certain conditions milk may also be a vehicle of poliomyelitis.

Milk-borne epidemics. — Reference has been made to the fact that prior to the beginning of the twentieth century epidemics of milk-borne disease were not always recognized or recorded, so that it is impossible to state accurately the number that occurred. Nevertheless, from the available records up to 1909, over 700 milk-borne outbreaks of disease have been compiled, of which 179 occurred in the United States. Between 1909 and 1927 there were 612 additional epidemics of milk-borne disease reported in the United States alone, despite the fact that this era includes the period during which pasteurization saw its greatest development.

This is additional presumptive evidence to show that milk-borne epidemics of disease were at first unrecognized and unrecorded.

The following table shows the number of recorded outbreaks of the more common milk-borne diseases which occurred in the United States between 1907 and 1926.

TABLE 12

REPORTED EPIDEMICS OF COMMON MILK-BORNE DISEASES IN THE UNITED STATES, 1907–1926

DISEASE	EPIDEMICS	CASES
Typhoid fever	479	14,968
Septic sore throat	42	21,045
Scarlet fever	40	3,939
Diphtheria	26	971

As we approach the present period in sanitary history the information concerning milk-borne disease becomes more complete and accurate. The subject was carefully reviewed recently by the Committee on Milk Production and Control of the White House Conference on Child Health and Protection, the preliminary report of which was published in *U S Public Health Reports* for April 3, 1931. (The final report, published by the Century Company, has subsequently made its appearance in book form.) The following information concerning the rôle of milk in the spread of disease was compiled by the Committee.

TABLE 13

MILK-BORNE EPIDEMICS OF DISEASE IN THE UNITED STATES, 1924–1929

DISEASE	EPIDEMICS	CASES	DEATHS
Diphtheria	8	208	1
Dysentery	1	8	0
Gastro-enteritis	4	391	0
Paratyphoid	3	93	1
Poliomyelitis	1	11	2
Scarlet fever	34	1,974	10
Septic sore throat	22	4,161	76
Typhoid fever	177	4,019	281
Undulant fever	8	41	0
All diseases	258	10,906	371

In 1929 alone there were 44 epidemics of milk-borne disease which were responsible for 1,959 cases of disease and 48 deaths.

Of these epidemics 13 were traced to chronic carriers of disease; 18 to ambulatory cases or sick persons who continued to work; 5 apparently to infected and unsterilized bottles returned from homes where a case of disease prevailed; 4 to the use of a polluted water supply; and only one epidemic is attributed to diseased dairy cows. Carriers and cases of disease occurring at the dairy were responsible for 31 out of the 44 epidemics, or 76 per cent; for 1,836 cases of disease, or 90 per cent of the cases; and for 23 deaths, or 51 per cent of the deaths.

In recent years Dr. George H. Bigelow, former State Commissioner of Public Health for Massachusetts, and some of his associates, have studied the epidemiology of milk-borne diseases in Massachusetts. The most recent of these studies is presented by Bigelow and Feemster in the *Journal of the American Public Health Association* for June, 1933, under the heading, "Milk-Borne Disease in Massachusetts, 1930–1932." Information is presented to show that since 1911 epidemics of milk-borne disease have been diminishing. In the period from 1911 to 1915 there were 9 milk-borne epidemics per year, while between 1930–1932 there were only 3 epidemics per year. Similarly, the cases per year due to milk-borne disease have diminished from 851 to 93. All of the outbreaks traced to milk during 1930 to 1932 were due to raw milk. In one instance, the milk was infected in the bottling machine, after pasteurization, by an employee who was a missed case of scarlet fever.

Most of the epidemics of milk-borne disease in Massachusetts and in other parts of the United States in recent years have occurred in small country towns and rural sections and in cities where the population varied from 5,000 to 25,000. These are the localities where raw milk is still being used, since the milk supplies of the larger cities and towns have been protected by pasteurization. Since over 50 per cent of the population of the United States still resides in rural areas and in small towns and cities, the transmission of disease through infected milk in these places continues to represent one of their major public health problems.

Bigelow and Feemster estimate that from 80 to 85 per cent of the milk sold in Massachusetts in 1931 was pasteurized. The following table indicates the extent to which milk was pasteurized in the cities and towns of Massachusetts in 1931, according to the population group to which they belonged.

TABLE 14

USE OF PASTEURIZED MILK IN MASSACHUSETTS, 1931

POPULATION OF CITIES	QTS SOLD DAILY	QTS PASTEURIZED DAILY	PER CENT PASTEURIZED
50,000 and over	1,030,933	990,536	96 0
25,000–50,000	201,943	180,651	89.5
15,000–25,000	222,810	178,154	80.0
10,000–15,000	96,332	57,657	60 0
5,000–10,000	137,450	73,920	53.7
Under 5,000	174,000		
Total	1,863,468	1,480,918	79.5

Epidemics due to milk products. — Apparently milk is far more significant than milk products as a vehicle of disease. According to the report of the White House Conference on Child Health and Protection there have been recorded only five epidemics due to infected ice cream; three epidemics due to infected cheese; and only one epidemic due to infected cream. Of the five ice cream epidemics, three were outbreaks of typhoid fever, one of scarlet fever, and one of septic sore throat. Of the three epidemics due to infected cheese, one was an outbreak of typhoid fever, another of a streptococcic infection, and the third of a gastro-intestinal infection. The epidemic due to cream was an outbreak of typhoid fever.

Discussion of specific epidemics. — The history of milk-borne disease is so replete with epidemics that it would be difficult indeed to select any particular disease as being more representative than another. The history in each case is essentially the same. Milk consumed in the raw state has usually been the vehicle, and where pasteurized milk was the vehicle, it has always been due to infected milk that had been pasteurized imperfectly, or to milk that was infected following pasteurization. The infection always follows the route of the milkman and affects mostly those who consume the milk. Milk-borne epidemics are apt to affect the more well-to-do than the poor, since the richer people in society are greater consumers of milk. Cleanliness of production does not necessarily protect a milk supply against infection. Epidemics of disease have even been associated with the best certified milk supplies where every precaution was taken apparently to supervise the health of the employees, the health of the cows, the sanitary quality of all milk utensils, and the milking methods. There is only one way

to insure the safety of a milk supply, and that is by pasteurization.

Although descriptions of specific milk-borne epidemics will not be included here, reference should be made to some of the epidemiological facts associated with the important diseases transmitted through milk. This will necessitate a brief discussion of some of the specific diseases transmitted through milk as well as fleeting reference to a few of the outstanding milk epidemics.

Tuberculosis. — Tuberculosis has been altogether too prevalent to make it possible to detect the disease in epidemic form. In fact it has been endemic all the time. Furthermore, the possible relationship of milk to tuberculosis in man was not thoroughly recognized until almost a generation after the discovery of the tubercle bacillus by Koch in 1882. For many years Koch maintained that all tubercle bacilli were identical regardless of their animal origin, and later, that each type was specific for the animal species in which it was found. The first point of view was disproved by the work of Dr. Theobald Smith of the Harvard Medical School, who in 1896 and 1898, demonstrated that human and bovine tubercle bacilli were distinct varieties or species.

The establishment of the thesis that tuberculosis in man and tuberculosis in cows were due to different strains of tubercle bacilli, naturally led to the query whether bovine tuberculosis could be transmitted to man. The subject was investigated by independent groups of workers — the Gesundheitsamt in Berlin, the British Commission on Tuberculosis in London, and the Research Laboratory of the New York City Board of Health in New York — and each came to the conclusion that bovine tuberculosis was transmissable to man. It is particularly the non-pulmonary forms of tuberculosis, like glandular, intestinal, meningeal, and generalized tuberculosis, which are transmitted from cattle to man. This is especially true among children in the preschool age group; to a lesser degree in the age group 5--16; and to a very small extent in adults, 16 years of age and over.

Numerous attempts, made both here and abroad, to isolate tubercle bacilli from raw and pasteurized milks have invariably yielded the same result, namely, that the raw milk available in large cities frequently contains living tubercle bacilli. Among the more recent studies is that of Tonney, White, and Danforth in

Chicago in 1927, who examined 16,700 samples of raw milk and found 1,448 or 8.66 per cent infected. This investigation, like others, demonstrated that the tubercle bacilli in milk were of bovine origin.

The infection of milk with bovine tubercle bacilli is accomplished either because the tuberculous lesions in the cow are present in the udder, or because the milk has become contaminated with cow manure which contained living tubercle bacilli. Since cows ordinarily swallow their saliva, those suffering from pulmonary tuberculosis may infect the whole alimentary tract and the feces of such animals generally contain living tubercle bacilli.

There are two ways of combating the spread of tuberculosis through milk. One is to eliminate all tuberculous cows from milk production. This is accomplished by means of the tuberculin test and the establishment of the accredited herd plan. Such a campaign has been waged extensively by the U.S. Government in coöperation with the state governments since 1917. It is an expensive and laborious procedure and of doubtful permanent value as far as universal public health protection is concerned. On this basis communities have been advised and urged to enact legislation requiring all milk to come from tuberculin tested animals or to be pasteurized. Unfortunately such protection of the milk supply against tuberculosis does not protect it simultaneously against typhoid fever, scarlet fever, septic sore throat, etc. The alternative method of obtaining protection against tuberculosis depends on effective pasteurization. This destroys not only the germs of tuberculosis, but likewise other pathogenic bacteria. While every reasonable effort should be made to eradicate tuberculosis, and a combination of the tuberculin test and effective pasteurization is most desirable, the chief emphasis should be placed on pasteurization as the effective means of eliminating bovine tuberculosis as a human public health problem.

Undulant fever.—This disease for years was associated only with goats and goat's milk but in recent years has assumed added importance for man. Malta fever was a well-known disease associated with the Island of Malta and the consumption of raw goat's milk. In 1887 Bruce discovered that Malta fever was caused by a germ, and in 1893 he called the germ Micrococcus melitensis. Subsequently, through an importation of infected goats, Malta fever was introduced into the United States. It has become widely

distributed and is now regarded as endemic in Arizona, New Mexico, and western Texas.

In 1897 Bang and Stribolt of Copenhagen discovered that infectious abortion in cattle and swine was due to a bacterial infection with an organism which they called Bacillus abortus. In 1918, Dr. Alice Evans, now of the U.S. Public Health Service, demonstrated that the organisms responsible for Malta fever and contagious abortion in cattle were simply two different varieties of the same organism. Subsequently a third strain or variant of the same organism, which affects hogs, was also discovered. The organisms have been named in honor of Bruce, their original discoverer, and are known today as Brucella melitensis (Malta fever, Brucella abortus (bovine abortion and undulant fever), and Brucella suis, the porcine strain.

That Brucella abortus could be responsible for undulant fever in man was first demonstrated by Keefer, an American, in 1924. Subsequently other human cases were reported by a variety of American observers. It was also demonstrated that the organism responsible for undulant fever could be recovered from raw milk obtained from cows where infectious abortion had been known to exist. At Ithaca, N.Y., where the disease was carefully studied by Moore and his associates, it was found that from 40 to 50 per cent of the cows that had aborted harbored Brucella abortus in their udders. An examination of the raw market milks sold in this territory showed that approximately 20 per cent of the samples contained Brucella abortus in sufficient numbers to produce lesions in guinea pigs. Up to July, 1929, a total of 1,296 cases of undulant fever had been reported in 43 states. Of these cases less than 3 per cent were in children under 3 years of age. About 17 per cent of the cases were reported from Iowa, and of these over 50 per cent were in residents of farming communities.

The control of undulant fever consists in part of eliminating infectious abortion from dairy herds. While such a campaign is desirable it is evidently an expensive and tedious procedure. Therefore, recourse must be had once more to the protection afforded by effective pasteurization.

Septic sore throat. — One of the most important diseases transmitted through milk is septic sore throat which ranks second only to typhoid fever. That septic sore throat could be transmitted through milk was recognized in South Kensington, Eng-

land, as early as 1875. However, in the United States, it did not receive the prominence and consideration it deserved until an explosive outbreak of septic sore throat affected the best residential districts in Boston, Brookline, and Cambridge, Mass., in 1911. Over 2,000 cases occurred in these three areas, and fully 85 per cent of the cases were either regular patrons of the milk supply involved or had used the milk immediately before the outbreak occurred. The supply in question was one of the best milks available in Boston. It was produced under excellent sanitary conditions within 30 miles of Boston, from healthy, tuberculin tested cows, and was under expert laboratory supervision. Unfortunately it was used as raw milk. Although so many cases were associated with it, it represented but 1 per cent of the milk supply of Boston, 2 per cent of Cambridge, and 7 per cent of Brookline. Forty-eight deaths resulted from this epidemic. In 22 per cent of the households affected there were 3 or more cases. The disease occurred twice as frequently in females as in males, and adults suffered more in proportion than children. About two-thirds of the fatalities occurred at ages above 55 and one-third at ages above 75. A considerable number of these fatalities were in individuals known to have impaired hearts or other organic defects.

A second historic epidemic of septic sore throat due to milk occurred in Chicago during December, 1911, and January and February, 1912. It is estimated that over 10,000 cases occurred during this epidemic. The milk involved was supposedly pasteurized, but investigation disclosed the fact that prior to the outbreak of this disease, there had been wide fluctuations in the temperature of pasteurization employed. In fact a temperature as low as 130° F. had been employed on several occasions.

Another famous milk-borne epidemic of septic sore throat occurred at Lee, Mass., during July, 1928. Although the population of this little town was only about 4,000, there were approximately 1,000 cases and 40 deaths. Only 20 per cent of the cases and 3 per cent of the deaths were in children under 16. In the age group 45 to 59 there were 19 per cent of the cases and 31 per cent of the deaths, whereas in the age group 60 and over there were 11 per cent of the cases and 60 per cent of the deaths. The milk supply responsible for the outbreak was a raw milk. This epidemic was investigated with great thoroughness by the State

Department of Health. Cases began to appear in the community on June 19, and the maximum number reported for one day occurred on July 1. Compulsory pasteurization was required on July 7, after which the epidemic subsided rather abruptly. The last case was reported on July 24 and was probably due to contact infection obtained from nursing service. Hemolytic streptococci were isolated from the udder of an infected cow, from her milk, from the throat of the milker's child supposedly infected by its father, and from the blood, ears, and throats of patients. It seems probable that the initial infection occurred in the milker and was therefore of human origin.

One of the questions associated with septic sore throat is whether the infection is of human or bovine origin. Mastitis in the cow due to streptococci may be of two varieties; that due to Streptococcus mastiditis and the variety due to Streptococcus epidemicus. The latter is the organism which causes septic sore throat in man, and is believed to be of human and not of bovine origin. When the cow's udder becomes infected with Streptococcus epidemicus it is believed that the infection of the teat occurs from an infected human (milker), with the later invasion of the milk ducts. There the organism survives and multiplies and later makes its way into the milk supply. The organism may be present in the udder in large numbers before any physical or visible signs of mastitis appear. Accordingly the only safeguard against milk-borne septic sore throat is effective pasteurization.

Scarlet fever. — This disease is due to the Streptococcus scarlatinae and may also be transmitted by milk. Milk has been a more frequent vehicle of scarlet fever in the past than it is today. Although there were 34 milk-borne epidemics of scarlet fever reported in the United States during 1924 to 1929, resulting in 1,974 cases, there were only 10 deaths. Epidemics of the disease are associated either with the use of raw milk or milk that has been pasteurized improperly. The original infection seems to be of human origin and is introduced into the milk through carriers or cases. There is also a possibility that the infection may be transmitted to the teat or udder of the cow whence it may make its way into the milk supply. The solution of milk-borne scarlet fever is also effective pasteurization.

Diphtheria. — Diphtheria as a milk-borne infection is of minor importance today. This is due to the rapid extension of pasteuriza-

tion for city milk supplies and to the spread of diphtheria immunization. During 1924 to 1929 there were only 8 milk-borne epidemics of diphtheria reported in the United States, which resulted in 208 cases and only one death. The infection of the milk is supposed to be of human origin, the infection coming usually from an active case or carrier. It is also believed that the infection may be temporarily transmitted to the teat or the udder of the cow and that the milk may become infected in that way. Milk-borne diphtheria can be eliminated entirely through the use of effective pasteurization.

Typhoid fever. — Typhoid fever is still the most important milk-borne disease. During 1924 to 1929 it was responsible for 177 out of 258 epidemics of milk-borne disease reported in the United States. In these epidemics, which did not include tuberculosis, it was responsible for 37 per cent of the cases and 76 per cent of the deaths that were reported. Although typhoid fever epidemics due to milk have been diminishing in incidence due to the introduction of pasteurization, they still represent a serious menace to the public health wherever milk is consumed raw. As the use of raw milk is rapidly being limited to the rural districts, milk-borne typhoid fever is becoming relatively more important for country dwellers than for city residents.

Nevertheless the greatest milk-borne epidemic of typhoid fever in recent years occurred in Montreal from March 1 to July 16, 1927. During this period there were 5,014 cases and 488 deaths from typhoid fever reported. The epidemic was associated with one of the largest milk routes in the city. The milk supply was supposed to be pasteurized. On investigation it was found that the foreman of the pasteurizing plant was a typhoid carrier and that the pasteurizer was in a leaky condition. A second peak in the incidence of typhoid fever during this epidemic was attributed to the failure of the same plant to pasteurize all the milk since more raw milk was delivered to the plant than was actually run through the machine. The epidemic must therefore be associated with the consumption of raw and improperly pasteurized milk.

Another milk-borne epidemic of typhoid fever that is worthy of note is the outbreak that occurred at Lincoln, Mass., in December, 1926. This outbreak also occurred on a raw milk supply and was due to the contamination of the milk by a known typhoid carrier. The carrier had migrated from New Jersey to Connecticut and

thence to Massachusetts, and in each case, information was forwarded to the State Health Commissioner that the carrier was taking up residence in his jurisdiction. At Lincoln, where the carrier was employed on a farm, he was informed by a representative from the State Health Department that he must not have anything to do with the milk supply. The farmer's wife was likewise instructed not to allow the man to handle the milk, or to engage in milking. Nevertheless, he participated in milking, with the result that an epidemic was initiated which affected approximately 50 individuals and caused 5 deaths. An interesting aftermath of this epidemic was disclosed when one of the cases developed into a carrier, thus establishing what may be called the immortality of the typhoid bacillus.

The infection of milk with typhoid organisms is of human origin exclusively. Sometimes the introduction of the infection is very direct, as for example, by the fecal-infected fingers of carriers or active cases of the disease. Less frequently the infection is introduced indirectly, as through the use of infected water and through the medium of flies. The sterility of milk utensils is also of the greatest importance in the elimination of the disease. Since carriers and cases in the early stages of disease are not easily recognized or controlled, the only certain safeguard against milk-borne typhoid infection is effective pasteurization and its subsequent protection.

What has been said about milk-borne typhoid fever is essentially true for paratyphoid fever, dysentery, cholera, and the non-specific diarrheal diseases of infancy and childhood that are of bacterial origin. Cleanliness, elimination of hand contamination of milk supplies, elimination of flies and polluted water supplies, prompt and adequate cooling of all milk as soon as it is drawn, and finally, efficient pasteurization are the methods by which the morbidity and mortality from these diseases have been brought largely under control.

Inspection and scoring of milk supplies. — When city milk supplies were first brought under municipal health department supervision, emphasis was placed not on sanitary methods of production and handling but on the detection and prevention of gross adulteration, such as skimming, watering, and the addition of chemical preservatives. At the close of the nineteenth century it is estimated that fully 50 per cent of the samples of milk exam-

ined by the chemists of the New York City Health Department were adulterated.

But the rapidly accumulating evidence that milk may be an important vehicle of disease effected a change in the emphasis on the supervision of city milk supplies. In 1896 the New York Board of Health modified its sanitary code to require that all milk sold in the city must comply with the sanitary rules and regulations of the Board and could be sold only after a permit had been issued. Furthermore in 1906 New York modified the definition of adulterated milk to include all milk kept at temperatures above 50° F., a ruling which has not been without its disadvantages, since it was implied that milk (and other foods) kept at a temperature below 50° F., were surely above reproach. Attempts were made, by educational methods and by inspections, to secure approval of this regulation. In the same year farm inspections were initiated in an endeavor to improve the sanitary quality of the milk at the point of production. As an aid to inspection a dairy "score card" was employed, and educational propaganda on the requirements of sanitary milk production instituted among producers. These efforts resulted in a marked improvement in the bacterial quality of the milk supply within the next few years.

The first dairy score card to be used in the supervision of city milk supplies was developed in 1904, by Dr. W. C. Woodward, former health officer for Washington, D.C. A maximum rating of 100 points was divided among items listed under equipment and methods. Attention was also directed to the health and cleanliness of the cows. Since then numerous modifications of the score card have been developed, with variations on the relative values assigned to the different items, but maintaining in general, its basic form and principles of evaluation. Since the method of production, *i.e.*, the sanitary procedures carried out, are of more significance than the buildings and machinery involved, usually about 40 points out of 100 are allowed for equipment and about 60 points for methods.

The advantages of a dairy score card are as follows: 1. it tends to focus attention on and to evaluate the important items of sanitary significance; 2. it tends toward uniformity and comparability in all dairy inspections; and 3. because of its definiteness it can be used for educational purposes with the farmer. Unquestionably

the use of the score card has had distinct value in bringing about improvement in the production of clean and normal milk.

There is one serious deficiency inherent in all score cards, namely, the subjective or personal element, since different inspectors using the same score card will vary somewhat in their estimates of the same dairy. To avoid this personal factor, score cards in which each item is marked either "yes" or "no" instead of a definite percentage rating, are sometimes used. New York City employs such a dairy score card and finds its use effective.

Requirements of sanitary milk production. — The production of clean, wholesome milk of low bacterial content is fundamentally dependent on intelligent methods of milk production rather than on expensive equipment. While a modern and expensive barn is desirable for housing cattle in decency and comfort, it is not essential for sanitary milk production. The emphasis must be placed on clean animals, clean hands, sterile milk utensils, and prompt and adequate cooling of the milk. These requirements do not necessitate expensive equipment but rather the use of intelligence. Milk must be regarded as an excellent culture medium for microbic development, and the object of sanitary milk production must be the elimination and control of microbic infections in milk through aseptic and antiseptic precautions.

The possible sources of bacteria in milk are legion. They may come from the udder, teat, or coat of the cow or the hands of the milker; they may be introduced into the milk with the dust of the stable air, the dust from the milker's clothing, the wind-swept dust from the barn yard, or the numerous flies that are associated with most dairy barns. They may arise from the use of unsterile milk pails, unsterile filters, strainers and straining cloths, and from unsterile vats, coolers, pumps, bottle fillers, separators, clarifiers, homogenizers, bottles, bottle caps, and the other dairy equipment with which the milk may come in contact.

In order to eliminate these potential sources of bacteria in milk, various precautionary measures must be taken before the milking begins. The cows should be well cleaned and the udder wiped with a clean, moist cloth. Clipping the udder and hindquarters of the cow greatly reduces contamination from these areas. Washing the udder with a solution of hypochlorite of lime shortly before milking also diminishes the bacterial count in the freshly drawn milk. The hands of milkers may be disinfected in the same manner,

and the importance of milking with clean and dry hands is obvious. In the production of certified milk milkers are required to wash their hands after milking each cow. An effort is often made to eliminate the hazards of hand milking by substituting milking machines, but such equipment, in addition to being expensive, requires unusual care to keep all parts clean and sterile. The use of sterilized small-mouth milk pails diminishes contamination from the air and from the body of the cow, and eliminates the contamination of the milk from organisms surviving ordinary washing. The milk should be removed at once to a milk room kept free from dust and flies where straining through sterile cotton pads made up with cheese cloth or cotton flannel still further reduces contamination from hair and skin cells. Freshly drawn milk should always be cooled promptly to 40° F., if possible, through the use of sterile and effective equipment. The handling of milk after efficient cooling depends upon its ultimate destination. If for immediate delivery to the consumer the milk may be run into cans or in bottles. If for long distance transportation, tank cars or tank trucks are sometimes used. Whatever the container it should be clean and sterile. Furthermore, the milk must be kept cold in transit. If milk is fresh, if it has been obtained with proper sanitary precautions, and is then kept properly refrigerated until it is consumed, it should have a low bacterial count and be reasonably safe. If the milk is pasteurized before it is bottled and delivered to the consumer, it is important that all of the equipment with which the raw and pasteurized milk comes in contact should likewise be clean and sterile.

In the production of milk of low bacterial content attention must be directed toward the elimination of flies as a source of contamination. The common fly and the stable fly breed in decomposing organic matter, and especially in stable manure, and may transport thousands of microorganisms from this and other objectionable sources. Such microorganisms may multiply in warm milk, thus hastening its decomposition, or they may possibly be pathogens of human origin and thus be able to transmit disease. For this reason, as well as for aesthetic reasons, the elimination of the fly from the milk supply is important. The complete elimination of flies from dairy barns is an exceedingly difficult task. Satisfactory conditions can be produced if an effort is made to keep the stables clean by removing all the manure two or three times

a day. It may be stored in dark, fly-proof pits, or transported to the fields in water-tight, covered wagons. In sizeable dairy barns manure can be removed conveniently by means of a bucket system operating on an overhead trolley. Manure should not be allowed to accumulate in large piles near the barn, as during the fly-breeding season it becomes a breeding place for flies, which in turn constitute a menace to sanitary operations. Proper screening of barns and milk rooms and the use of fly-repellents in the barn give additional protection.

Although expensive barns are not necessary for the production of clean milk of low bacterial content, the type of stable floor is an important consideration from the standpoint of cleanliness. Wooden floors are objectionable. Cement or concrete has certain advantages, but is not without drawbacks from the standpoint of comfort. In recent years special types of flooring made of compressed cork and asphalt have been developed which may be kept clean and are warm, non-absorptive, and durable.

Certified milk. — With the recognition that mother's milk differs in chemical composition from cow's milk there arose a demand for modified milk in infant feeding. Simultaneously, however, came the realization that really clean and wholesome cow's milk was not available for purposes of modification. Accordingly in 1891 Dr. T. M. Rotch succeeded in interesting Messrs. Walker and Gordon in establishing a "certified milk" farm at Charles River Village near Boston, and used this milk for producing modified milk for infant feeding. Since then the production of certified milk has gradually increased, and this type of milk has been regarded as the purest obtainable. Although it is usually consumed in the raw state, an increasing proportion is now being pasteurized. Essentially, such milk is produced from healthy cows which are under constant veterinary supervision with special attention to freedom from tuberculosis. The milkers are also subject to regular lay and medical supervision. The milk itself must be produced in accord with the best sanitary practices and is subject to daily examination. Finally, the milk must be "certified" by a medical milk commission composed of some of the leading pediatrists in the locality served, who guarantee that the milk has been produced according to certified milk requirements. Certified milk is specified to contain at least 4 per cent butterfat and not more than 10,000 bacteria (more in some

cities) per cubic centimeter at the time it is delivered to the consumer.

In recent years certified milk has been produced from cows guaranteed by examination to be free of contagious abortion in order to eliminate the possibility of transmitting undulant fever in this way. Some attempts have also been made to increase the vitamin D content of such milk and to use such milk for the production of soft curd milk.

Unfortunately, in spite of all the precautions that are taken to make certified milk a safe milk, it has been responsible for a number of outbreaks of disease. It is the best milk available from the standpoint of nutritional and bacterial quality, but for absolute safety it should be pasteurized.

Grading of milk. — All milks are not alike in composition, cleanliness, or nutritive quality. In fact, the variations are pronounced and significant. These differences led the late Professor Sedgwick to insist that we should speak of *milks* rather than merely of milk. From the standpoint of relative cleanliness, relative richness, and relative safety numerous gradations occur.

Since milks must be regarded as variable in quality, both nutritionally and bacteriologically, and the production of those of highest quality involves expensive procedures and equipment, it is logical that milks of superior quality in food value, as shown by the butterfat content, and of highest safety because of the absence of tubercle bacilli and the minimal occurrence of other bacteria, should command a higher price than milks which do not possess these advantages. These considerations led the New York Board of Health in 1911 to introduce a system of grading milks, dividing them into three grades, A, B, and C. Certain bacterial standards were prescribed for each grade. These standards have been modified on subsequent occasions with the general improvement in milk production. The stimulus to produce milk of a given butterfat content and a certain low maximum bacterial count has been greatly aided by offering the farmer a bonus for such a product. Grading thus rewarded the farmer for his added care and assured the consumer a superior product, although at a higher price.

In May, 1926, the New York Board of Health prohibited the sale of Grade C milk. Milk of grades A and B must be pasteurized before being sold, and only certified milk is allowed to be sold raw. Other cities followed the New York plan, among them Boston,

where all milk other than certified must be pasteurized, and where Grade A milk is distinguished from ordinary market milk (B). To meet the Massachusetts requirements, Grade A milk must not contain more than 250,000 bacteria per cubic centimeter in the raw state, and not more than 25,000 bacteria per cubic centimeter after pasteurization. In addition such milk must also contain at least 4 per cent butterfat. Such a standard guarantees milk of suitable sanitary and food value.

While these requirements may be met in the northern United States it is impossible to impose the same regulations for every section of the United States. So-called standards must necessarily vary with the size and character of the producing areas, and with other factors incident to the region served. Urban requirements, transportation problems, and the progressiveness in sanitary milk production and handling are the dominating factors. Each situation must be studied separately and standards adopted which will satisfy local conditions. As a given situation improves, the standards for each grade of milk can be elevated. In general, however, the practice of grading milk is exceedingly desirable from the public health point of view and its adoption should be encouraged.

Pasteurization. — In the preceding pages the process of pasteurization has been mentioned as a necessary part of the protection of milk supplies. Its origin and the discoveries and practices leading to its widespread use are fundamental to sanitary science. From time immemorial man has heated his foods to make them more palatable, digestible, and safe. The application of heat to food preservation over long periods of time was first made only a little more than a century ago. In 1809 Appert was granted a patent in France on a process by means of which he demonstrated that foods in sealed containers could be preserved indefinitely if the sealed jars were submerged in boiling water for an adequate period of time. Even before Appert, Scheele in 1782, heated vinegar to prevent it from spoiling. Others likewise utilized the same idea. However, it was Pasteur's work on the prevention of the diseases of wines and beers, and their preservation, that led eventually to the adoption of a similar method of treatment for milk as a means of rendering it safe and prolonging to some extent its keeping qualities. In 1860 to 1864, Pasteur heated wine in bottles at temperatures ranging between 50° and 60° C. (122° and 140° F.) for a "few minutes" and succeeded in killing the bacteria

and yeasts which were causing the souring of wine. Applying the same process in his later experiments on beer, and using temperatures of 55° to 60° C. (131° to 140° F.), he succeeded in preventing the souring action by the invading germs. Since then, the process, with important modifications, has been widely applied to milk treatment and has been designated "pasteurization" in honor of Louis Pasteur. If Pasteur had made no other significant contribution to the welfare of man, the process, pasteurization, would be an enduring monument in his honor, for by its use in milk alone it has saved innumerable lives from disease or death.

When pasteurization was first employed commercially on milk supplies its purpose was primarily to defer souring or spoiling rather than for public health protection. The principle followed was the use of high temperatures for very short periods of time, or what has since been called "flash" pasteurization. Complicated machines with steam heated surfaces which quickly became coated with non-conducting films of milk solids were used. Many bad practices crept in. The temperature control was ineffective and pathogenic bacteria were not always destroyed. The milk souring bacteria found in all fresh milks were often eliminated so that the milks underwent incipient protein change instead of turning sour. A cooked taste could also be readily detected. These defects in method and product gave pasteurized milk a bad reputation, the evil effects of which required a generation or more to overcome.

It is important to remember that pasteurization is not synonymous with sterilization. It does not necessarily destroy all the bacteria in milk, but is selective in its effects. "Perfect" pasteurization which is defined as the treatment of milk at a temperature varying between 142° and 145° F. for 30 minutes, destroys all of the pathogenic bacteria likely to be found in milk (including the tubercle bacillus, the hemolytic streptococci of septic sore throat, and the bacteria of undulant fever, typhoid fever, scarlet fever, and diphtheria), but does not destroy all types of the lactic acid or milk souring bacteria. Thus, milk so pasteurized sours much as normal milk does, and the consumer is protected against milk-borne diseases. Furthermore, "perfect" pasteurization imparts little if any cooked taste to milk; nor, if the milk is properly cooled, does it affect the cream line in milk. Although there may be minor changes in salts and protein it apparently does not affect the readiness with which the calcium and phosphorus salts in milk are as-

similated by the growing child. In short, it is one of the most useful processes which the human race has developed.

What, then, are the objections that have been raised against the use of pasteurized milk? Some of the objections, namely, that pasteurization destroys the lactic acid bacteria and that the physical and chemical properties of raw milk have been altered unfavorably, have been answered in the preceding paragraph. Perfect pasteurization simply does not do these objectionable things which critics have claimed. It has also been maintained that pasteurization favors unsanitary milk production; that it does not destroy the spore-forming bacteria; that it destroys vitamin C, the anti-scorbutic vitamin; that the toxic products which bacteria may produce in milk are not destroyed, and that the consumption of pasteurized milk was not the way nature intended milk to be used.

All of these objections disappear on informed analysis, and they represent not an indictment of pasteurization, but rather an exhibition of ignorance or an indictment of unsanitary practices in milk production. For example, the charge that pasteurization favors the production of dirty milk is disproved by the fact that hand in hand with the universal adoption of pasteurization in the United States there has been a marked improvement in the sanitary production of milk. Pasteurization is not designed as a substitute or safeguard for dirty milk. Dirty milk should be excluded from use altogether. Pasteurization is simply designed to insure safety to milk supplies just as chlorination is used to safeguard a filtered water supply.

It is true, however, that pasteurization does not destroy spore-forming bacteria; but such organisms should not be present in appreciable numbers in clean milk produced according to approved sanitary procedures. The charge therefore should be directed against unsatisfactory methods of milk production rather than against pasteurization. It is well known, however, that the development of spore-forming bacteria in milk is inhibited by the growth of the lactic acid bacteria, and since they will not develop in appreciable numbers until the milk has soured, and since sour milk is normally not used as food for humans, the objection against pasteurization on this count is likewise untenable.

Similarly, the objection concerning the survival of toxic bacterial products in milk is likewise without foundation. Such products

may be found in dirty, decomposed milk or in milk which is old and decomposed. In either case the milk should not be used as food either in the raw state or in the pasteurized condition. The objection is not one that can be lodged against pasteurization but one that should be directed against the consumption of dirty, old, and decomposed foods.

It is also unsound to maintain that pasteurized milk is not natural milk, for even raw milk is not natural milk. Raw milk contains numerous bacteria, cow dung, flies, dust, and dissolved metals and gases which are not normal to natural milk. The only way to obtain natural milk is the method of the suckling infant. Furthermore, milk is not the only food that is heated before being consumed. Examples are too well known and numerous to be mentioned here. The application of heat to food preparation has been one of the greatest discoveries of the race. It has added much to the enjoyment of life, and more important still, it has prevented the intestinal tract of man from becoming the zoological garden of the innumerable parasites which afflicted his ancestors, and which as we know were successful in terminating his unhappy existence at a tender age.

There remains therefore the objection that pasteurization lessens the anti-scorbutic vitamin in milk. This is true and cannot be denied. At the same time it must be remembered, however, that the amount of vitamin C present in raw milk is exceedingly small and is insufficient to protect an infant against scurvy. Furthermore it is true that pasteurization is not in reality responsible for the destruction of the vitamin. It is oxidation which is the cause, for if the milk is pasteurized in an atmosphere of carbon dioxide instead of air or oxygen, the vitamin C content is not diminished. It is likewise unwise for us to attempt to elevate milk to the position of the complete food. Excellent as it is as a food for man, it has certain deficiencies which have been noted earlier in this chapter. The simple addition of orange juice or tomato juice to the diet, even of the infant, immediately makes up the vitamin C deficiency of milk, and permits the individual to enjoy the protection which pasteurization affords.

The fact that the holding method of pasteurization has come into widespread use in the United States is not an accident. Its effectiveness, long ago demonstrated in the laboratory, has been verified by the more important proof of actual commercial prac-

tice. Infected milk consumed raw in one community where pasteurization was not required produced disease, whereas part of the same supply sold and used in another community after it had been pasteurized properly did not cause disease and death. The early methods of rapid or "flash" pasteurization were not always effective and did not provide the factor of safety which the holding method possesses. The holding method also eliminates any deleterious effects on the physical and chemical composition of the milk, and is preferable from this standpoint as well.

The conclusion that a temperature of 142° to 145° F. for 30 minutes is the best arrangement to employ in the pasteurization of milk is the result of much carefully controlled work on this subject. In many of these experiments, large quantities of milk were heavily seeded with cultures of disease-producing bacteria and pasteurized by the holding method. Attempts were then made to recover the living organisms that were inoculated in the milk. However, it has been the universal practice to adopt the thermal death point of the tubercle bacillus as the best index of the proper combination of temperature and time for effective pasteurization. The tubercle bacillus is more resistant to heat than other vegetative disease-producing bacteria transmitted through milk, because of its protective, waxy coating, so that if the tubercle bacillus can be destroyed by a certain temperature-time combination it is certain that the other vegetative, disease-producing bacteria that may be present in the milk will also be destroyed.

One of the most extensive investigations into commercial pasteurization occurred at Endicott, N.Y., the results of which were published by the U.S. Public Health Service in 1925 as *Public Health Bulletin No. 147*. The experiments brought together public health administrators, bacteriologists, engineers, and milk experts. As a result of these experiments pasteurization was defined in accord with the definition given earlier in this chapter.

In determining the thermal death point of the tubercle bacillus in milk it is important to eliminate the cooling effect of the air on the surface film of milk as well as the formation of foam or a pellicle on the milk. After taking these items into consideration, Dr. William H. Park, Director of the New York Health Department Laboratories, determined the death point for the tubercle bacillus at various temperatures and time periods. The results

were published in the *American Journal of Public Health* for 1927, and because of their importance are reproduced here.

TABLE 15

THERMAL DEATH POINTS OF MYCOBACTERIUM TUBERCULOSIS IN MILK, ACCORDING TO PARK

Temperature		Thermal Death Time in Minutes
Degrees C	Degrees F	
68.3	155	1
62.8	145	6
61.1	142	10
60.0	140	15
58.9	138	20
57 8	136	30

The preceding table indicates that the tubercle bacillus in milk is destroyed at 138° F. after 20 minutes. Since the tubercle bacillus is the most resistant of the vegetative pathogenic bacteria found in infected milk, it follows that the other pathogens are also destroyed at 138° F. after 20 minutes. As perfect pasteurization requires a minimum temperature of 142° F. and a minimum time period of 30 minutes, a minimum factor of safety of 4° F. and 10 minutes is provided. By experience this has been found to be ample for purposes of public health protection. In reality, however, the factor of safety is greater, since the temperature will hover in the vicinity of 145° F. throughout the pasteurizing period.

There are at least 5 methods of pasteurizing milk, each of which has been accepted by public health authorities. They are (*a*) the electric short time, high temperature type of pasteurizer; (*b*) the holding method; (*c*) the continuous flow method; (*d*) the vat method; and (*e*) pasteurization in the final container.

There are various types of electric short time, high temperature pasteurizers available today. One of the better known machines — the Electropure — requires the milk to flow continuously between two carbon electrodes through which an alternating current is passed. The temperature of the milk is elevated to 160° F. and every particle of milk is subjected to this temperature for at least 15 seconds. A committee of milk experts appointed by the American Public Health Association to investigate these electrical pasteurizers report in the *A.P.H.A. Year Book for 1932–1933* (Supplement to *A.J.P.H.*, v. XXIII, No. 6, June, 1933, p. 88) that

"pasteurizers of this type are a dependable means of producing a safe milk of satisfactory marketable quality." This type of pasteurizer has also been approved by the State Health Departments of New York and Pennsylvania.

In the holding method of pasteurization the milk is preheated to 143.5° F. before being sent into the holding tank. Here the milk is kept between 142° and 145° F. for 30 minutes. During this period the milk is agitated slowly but constantly, and all the milk is heated for the required time and temperature. The corners of this type of tank are rounded, and the tank is provided with flush outlet valves and leak-proof inlet valves. Arrangements are also available either for heating the foam on the surface of the milk or for eliminating it altogether. The tank is covered and as the milk is agitated no difficulty is experienced with pellicle formation.

The holding process in which milks are held at 142° to 145° F. for 30 minutes are invariably associated with the so-called regenerative system. According to this plan hot pasteurized milk is used to warm the incoming cold raw milk before the latter passes into the pasteurizer or holding tank. In this heat exchange a real economy is accomplished. After the milk is warmed in the regenerative system it passes to the preheater where the temperature is "boosted" to 143.5° F. after which it flows into the holding tank. The holder is generally a jacketed, enameled metal tank. Through the pocket hot water is circulated in order to maintain the temperature of the milk at the required point.

The continuous flow pasteurizer is one through which milk is passing continuously. Raw milk which has passed through the regenerative system and has been elevated to 143.5° F. is allowed to flow into a long, tubular coil. The velocity of flow is so regulated that at least 30 minutes are required for the milk to pass through the coil.

The vat method may be operated as a holding method or as a combination of pasteurizer and holding tank. The vat consists of a jacketed tank with or without a revolving, helical tubular coil. If a coil is available, cold milk can be introduced into the tank and hot water passed through the moving coil and the jacket, until the temperature of the milk is elevated to 143.5° F. The milk is then held for 30 minutes at the required pasteurizing temperature. After that, cold water and subsequently brine may

be circulated through the coil and the jacket, and the milk is cooled in the same tank. If the coil is not present, the milk is preheated to the pasteurizing temperature, after which it is introduced into the tank and held there at the proper temperature for the required period of time.

Pasteurization in the final container is theoretically the safest method of pasteurization, since all possibility of subsequent infection is thereby eliminated. The bottles are filled to the one-quart mark and are so designed as to allow for the expansion of the milk during heating. Each bottle is provided with a metal crown seal cap. The bottles are filled with milk at 100° F., sealed, and then carried on conveyors through a water bath in which the temperature of the milk is elevated to 143.5° F. From here, the bottles are passed through another hot water bath where they are held for 30 minutes. From here, they pass through cold water and ice water baths until the milk is cooled. Another method of pasteurizing milk in the bottle is by spraying the filled bottles in a special chamber with hot water. The milk may be cooled in the same way, by substituting cold water for the hot. Where milk is pasteurized in the final container, care must be exercised to insure the attainment of the proper temperature in the interior of each bottle.

Every pasteurizing device should be equipped with an accurate indicating thermometer and with accurate recording thermometers. The indicating and recording thermometers should agree. If the automatic recording thermometer is accurate, it represents an excellent record of the temperature of pasteurization throughout the pasteurizing period.

After the milk has been pasteurized, regardless of the type of pasteurizer employed, the heated milk should be cooled promptly to approximately 40° F. after which it is allowed to pass to the bottle filling machines, and thence into clean, sterile bottles. In the best installations the bottles are capped automatically, and are sometimes further protected with an outer paper cap which guards the mouth of the bottle from hand contamination. The bottled milk is kept cold until it is delivered to the ultimate consumer. After the pasteurization has been completed, all of the piping and machinery should be disconnected, and all vats, pipes, pumps, tanks, and other apparatus must be thoroughly cleaned and sterilized. In this way the next batch of milk

will be protected against the possible contamination from the last.

The milk industry has made remarkable progress since the beginning of the twentieth century in protecting and insuring the quality and safety of city milk supplies. Each day sees a difficult and large task which must be met and conquered. Milk, the perishable food, must be assembled in a clean and sweet condition from the limitless rivulets that trickle from a million farms or more, into mighty, white rivers, with the potentiality for good or evil. Then, each river must be purified and redistributed into still more limitless rivulets to almost every urban home in America. The process must be repeated day after day, every day in the year. That it has been accomplished with so much success is a tribute to the contribution which bacteriology, sanitation, and engineering have made to the protection and preservation of man's most precious food.

CHAPTER XV

CERTAIN UNCOOKED FOODS (MEATS, OYSTERS, FRUITS, VEGETABLES, ETC.) AS VEHICLES OF DISEASE

Infected water and infected milk are among the commonest and the most dangerous vehicles of communicable disease. They are, however, by no means the only foods that serve as vehicles of disease, certain other foods, such as uncooked meat, oysters, and vegetables, being able to serve in a similar capacity. The discovery of this fact was first made in the case of uncooked meat, the muscles of swine having been found in 1860 to have served as a vehicle of a parasitic worm, *Trichina spiralis*. Numerous epidemics of trichinosis have been studied since that time, and special measures of prevention are now established in many countries against this disease, but the best preventive is the simplest, namely, thorough cooking of all such products — pork, ham, sausages, and the like — as are derived from hogs.

Trichinosis or the pork-worm disease. — This disease, which is characterized by intense inflammation and irritation, with high fever, soreness, muscular paralysis, dropsical swellings and, in severe cases, death in from five to fifty days, is now known to be caused by a minute cylindrical worm barely visible to the naked eye, and therefore entitled to be called a microorganism, which, in the larval state, inhabits the muscles of man, swine, dogs, cats, rats, mice, rabbits, and guinea pigs, and many other animals, and in the mature state lives in the intestines of the same animals. The male is much smaller than the female, and when mature measures only about 1/18 of an inch in length. The female is stouter and longer, measuring when mature about 1/8 of an inch. The eggs are about 1/200 of an inch in length. The young trichinae, like young tapeworms, occur embedded in the muscles of the hog and various other animals and man; but, unlike the young tapeworm, the young trichinae are so small as to be quite invisible to the naked eye, and millions of them may exist in the flesh of a pig without producing any unusual appearance in the meat sufficient to attract the attention, unless with a microscope. When

first introduced into pork or human flesh the little worms are free and coiled up among the muscular fibers, but after four or

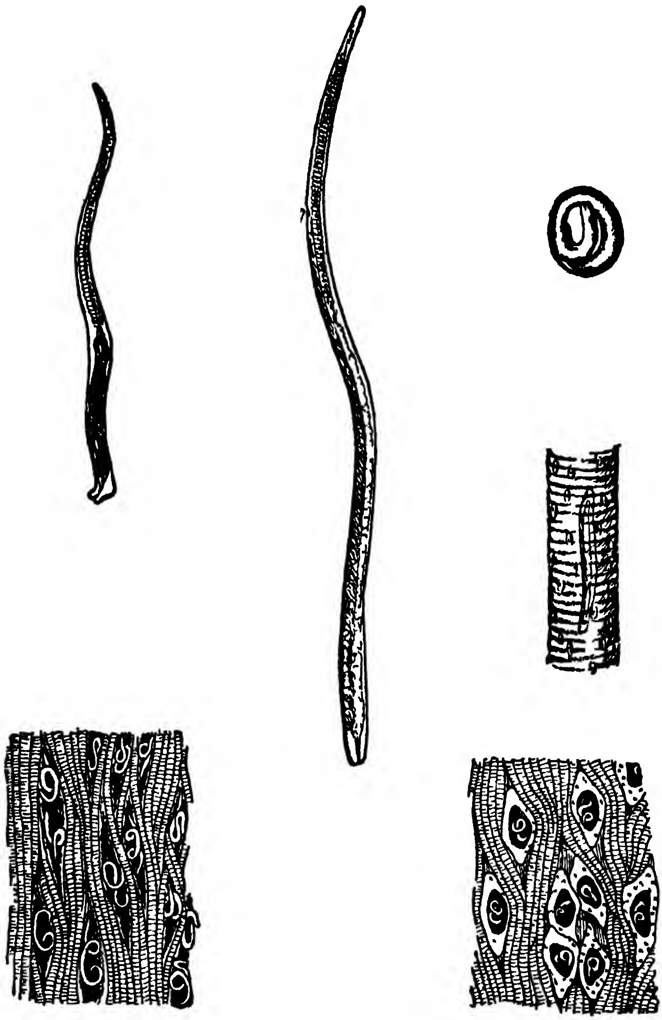


FIGURE 5. Trichina spiralis (male and female), showing worms and cysts in muscle tissue

five weeks they become enclosed in minute whitish, elongated oval or roundish cysts or capsules, due to the inflammation and irritation that they cause by feeding and living. After a year or

more these cysts become calcified, and are then visible to the eye as minute specks scattered through the muscles. When enclosed in the cyst, the worms become dormant, and they may live for years, and even some time after the death of their host. They can do no further harm unless swallowed by man or some other animal. Each cyst contains a little slender worm about 1/25 of an inch long, coiled up in two or three turns.

If pork or other flesh containing these worms — either free or enclosed in cysts — be eaten by man, they become liberated in the stomach, and, entering the intestine, attach themselves to its soft lining; and there, surrounded with abundant food, they grow very rapidly and become mature in about two days. Here the females live long enough to produce from five hundred to one thousand young worms each. As one ounce of pork sometimes contains a quarter of a million or more of the worms, it is not surprising that the millions of adult worms and their offspring, sometimes resulting from a single meal of raw swine flesh, should by their presence produce great irritation and inflammation of the intestine and violent diarrhea and vomiting, which are often the first symptoms in severe cases.

The young worms, almost as soon as they are born, begin to eat or force their way through the membranes of the intestine into the minute blood vessels and other organisms, thus vastly increasing the irritation. Eventually they become diffused through the entire system, and are found most abundantly in the groups of muscles nearest the abdominal cavity.

The duration of the disease, like its severity, is in direct proportion to the number of living trichinae swallowed, and varies from two weeks to three or four months. Even in many comparatively mild cases the suffering is intense, and the recovery slow and tedious. When all the worms have become lodged in the muscles and enclosed in cysts, the direct symptoms cease, and, if the strength of the patient has been kept up, recovery is probable.

Persons in robust health may be able to survive the attack of half a million or more of these flesh-worms, and recover; but in some very severe cases the numbers contained in human bodies have been estimated by reliable authorities to be as great as forty or sixty millions, and such cases usually result fatally.

The cysts containing trichinae were first observed in human

muscles in 1822; but the worms from similar cysts were first named and described by Owen in 1835. They were, however, only regarded as anatomical curiosities of no practical importance until 1860 when Zenker proved that they are capable of producing the severe and often fatal disease now known as trichinosis, but which had previously been confounded with typhoid fever, inflammatory rheumatism, or rheumatic fever, malaria, poisoning, and various other diseases. In the examination of the diaphragm muscles of 117 cadavers used in the anatomical laboratories of the University of Minnesota Medical School, Riley and Scheifley* found 20 cases of trichinosis, an incidence equal to 17.9 per cent. As far as is known, the subjects had never been recorded as exhibiting any symptoms of trichina infection. The authors present this evidence in support of their theory that trichinosis is far from being a rare disease in the United States today.

The means of prevention in the case of trichinosis is very simple, namely, thorough cooking, and the rarity of the disease among people who avoid raw or underdone swine flesh in any of its varieties establishes the efficacy of the remedy.

The question of infection by tuberculous meat. — After it was definitely established that tuberculosis in animals is transmissible to man, the question naturally arose concerning the dangers of consuming tuberculous meat. The germs of tuberculosis probably occur frequently in the muscles and other edible tissues of cattle, cows, calves, and other animals, but whether or not the consumption of such food is dangerous depends entirely on the effectiveness with which the bacteria are destroyed in cooking. In the United States the U.S. Bureau of Animal Industry and the various local and state health departments do not sanction the sale of tuberculous meat. All animals slaughtered and used in interstate commerce, according to legal requirements, must receive an ante-mortem and post-mortem examination by the trained veterinarians of the U.S. Bureau of Animal Industry. This applies to cattle, sheep, hogs, and any other animal that might be used as a source of human food. If the animal or its tissues are not to be shipped in interstate commerce, but are to be used within the state, then the U.S. Bureau of Animal Industry does not have any responsibility in the matter. The problem is then a local one,

* W. A. Riley and C. H. Scheifley, "Trichinosis of Man a Common Infection," *Jour. A.M.A.*, v. 102, No. 15, April 14, 1934, p. 1217.

and is handled through the veterinarians employed by the local department of health. In such cases the animal also receives an ante-mortem and post-mortem examination, and if found tuberculous, is not used for human food.

By providing such careful and rigid veterinary supervision over all animals used in interstate commerce — and the bulk of our meat supply today is subject to such supervision — it is possible to eliminate all animals or the diseased portions thereof, which might affect the public health. While this system is obviously very desirable, and perhaps the proper one for a country so bountifully supplied with food as the United States, undoubtedly a great deal of food is destroyed which could be rendered safe in this way. In Germany, for example, it is permissible to use tuberculous meat, if the meat is sterilized under governmental supervision. In this way the germs of tuberculosis and the germs of other diseases are destroyed, the food supply of man is conserved, a dangerous food is rendered safe, and a certain amount of cheap meat is made available. Germany also allows the use of horse meat for human consumption, a condition which would create great opposition, if introduced into the United States.

In conclusion, therefore, it is possible to state that the danger of infection from tuberculous meat is very slight, since tuberculous animals or their diseased parts are not used as sources of human food in the United States. In countries where they are so employed, the germs of tuberculosis are destroyed by scientifically supervised sterilization, or by adequate cooking.

Raw oysters as a vehicle of infectious disease. — The possibility of infection by raw oysters grown in sewage-polluted waters had been recognized by sanitarians, but not much emphasized previous to 1894. In that year the attention not only of sanitarians but of the whole world was drawn to the subject by a remarkable epidemic of typhoid fever among certain students of Wesleyan University, in Middletown, Connecticut, who had attended a college fraternity banquet on the 12th of October, and had there eaten raw oysters which were afterward proved to have been derived from sewage-polluted and probably typhoid-infected oyster-beds. A careful investigation was made at the time by Dr. H. W. Conn, Professor of Biology in Wesleyan University on behalf of the State Board of Health of Connecticut, whose report may be found in the *Seventeenth Annual Report of the State Board of Health of Connec-*

ticut for 1894, and also as Appendix Number Three of the *Supplement to the Twenty-fourth Annual Report of the Medical Officer of the Local Government Board for 1894–1895*, entitled "Oyster Culture in Relation to Disease," London, 1896, p. 152. This epidemic was so remarkable, so ably investigated by Professor Conn, and forms so complete a demonstration of the efficiency of raw oysters as vehicles of disease, that an extended abstract of the original paper is included here. The author says very truly:

"A more typical example of an outbreak of typhoid due to a single source of infection has hardly been found in the history of medicine, and the example furnishes a demonstration of a new source of danger for this disease.

"The use of raw oysters has before been suggested as a possible source of the spread of the disease. The readiness with which these absorb water, and the fact that they not infrequently lie in positions where contamination with sewage appears to be possible, has led to their being suspected in several cases. It has hitherto, however, not been possible to trace any distinct epidemic to them with anything like demonstrative evidence. The conditions which have occurred at Wesleyan have, however, been exceptionally well adapted to point out this connection. Indeed, if one had planned beforehand a series of experiments designed to prove the possibility of oysters as distributing typhoid, it would hardly have been possible to have devised a more satisfactory series of conditions than those which have obtained in this outbreak at Wesleyan."

Shellfish sanitation. — Before describing this epidemic, it may be well to discuss briefly the nutritive value of the oyster, the biology of oyster culture, and the sanitary safeguards which are necessary to insure a clean and wholesome supply of this important shellfish.

The oyster industry has grown in economic value to such a degree that at present it ranks as an important industrial pursuit. In 1927 approximately 30,000,000 bushels of oysters were harvested in the United States, the value of which approximated $50,000,000. The oyster is the only shellfish consumed in any quantity in the raw state, and on this account it has greater public health significance than clams, crabs, lobsters, shrimp, mussels, and scallops — other forms of shellfish — which are invariably consumed only after cooking. Furthermore, the consumption of

raw oysters is likely to continue, as the oyster is a succulent, delectable food, appealing to the taste of a great many people thus insuring a steady and probably increasing demand. Since it has been demonstrated that raw oysters may be a vehicle of disease, especially of typhoid fever, paratyphoid fever, acute food poisoning, and other intestinal infections, it is highly important that the sanitation of the oyster should be safeguarded.

The oyster has been a potential menace to health because in the past it was frequently floated in polluted, brackish water, sometimes even near a sewer outfall, just before it was marketed, in order to make it swell and to enhance its appearance, after which it was often consumed raw. Until recently comparatively little attention was given to the sanitary conditions under which shellfish were handled, or to the health of the operatives. Accordingly it is not surprising that the consumption of raw oysters has been found to be fraught with danger and that the sanitary supervision of the shellfish industry has come within the domain of public health practice.

Certain biological aspects of the oyster. — While the European oyster is bisexual or hermaphroditic, the American oyster is unisexual, and the millions of eggs which are eliminated by each female during the spawning season must be fertilized by the sperm from the male for reproduction. The mortality of the fertilized eggs and oyster larvae is high, by far the larger proportion being eaten by fish or swept away by tides and currents. During the swimming stage the oyster larva takes sufficient lime from the water to form the shell, and in about two weeks from the time the egg is fertilized the small oyster or "fry" settles to the bottom, and if able to attach itself to an old shell or other suitable support, its chance for survival is greatly increased. This is known as the setting stage, and it is customary, in certain districts, just before the set is expected, to throw shells upon the bottom, as hundreds of these small oysters will attach themselves to a single shell. The growth made from the spawning season, which occurs in July or August, to the following spring results in a considerable increase in size, and it is this stock, known as "spat" which is dredged up and planted on leased grounds. Under the law the seed oysters removed for transplanting may not contain more than 15 per cent of old shells, in order that the stock of shells may not be depleted for a subsequent setting period.

After the seed oysters have been planted on leased ground they are allowed to remain there until they have reached marketable size, a period requiring from three to five years. They are then dredged, and often removed to floats, so constructed that the water passes freely over the oysters. Here they are kept for two or more low tides, during which the oysters have an opportunity to cleanse themselves internally of mud, sand, and grit. This is readily accomplished, since the oyster passes from 15 to 20 gallons of water per day through its gills, when it is actively engaged in feeding during warm weather. It is important, of course, that the water in which the oysters are floated should be of unquestionable purity. After the "floating" process the oysters are brought to the docks, sorted into bushel baskets, placed in clean burlap bags capable of holding 1,000 oysters, sewed up, and properly tagged for shipping.

The nutritive value of the oyster. — Not only is the oyster a delectable food, but it is also excellent from a nutritional standpoint despite its high water content. The edible portion is rich in protein, contains from 1 to 5 per cent glycogen, sometimes referred to as animal starch, and from 1 to 2 per cent fat. It is an unusually good source of certain minerals, being rich in calcium, phosphorus, iron, and iodine. In addition, the oyster is a good source of vitamins A, B, and D.

Safeguarding the sanitary condition of the oyster. — Following the epidemic of typhoid fever in the winter of 1924–1925, ascribed to the consumption in the raw state of infected oysters in New York, Chicago, and Washington, the U.S. Public Health Service decided to "certify" the sanitary condition of oysters shipped in interstate commerce, through the cooperation of the various state departments of public health. As a result of extensive sanitary surveys, certain minimum requirements concerning the growing, harvesting, handling, transporting, shucking, and storing of the oysters and clams, and the sanitary facilities available at all plants handling such shellfish, were adopted, to which all shippers of oysters and clams, used in interstate commerce, would have to conform before their goods could be "certified."

In brief the requirements were as follows: All shellfish are to be grown in areas free of pollution and approved by the State Department of Public Health. Where purification of shellfish is permitted, it has to be done in accord with the requirements and under the

supervision of the State Department of Health. If shellfish are allowed to purify themselves by washing, they must be transferred to clean waters for at least seven days, and the temperature of the water must not be less than 60° F., in order to insure an adequate intake of water. When shellfish are floated the water must be above suspicion of impurity and above a certain minimum salinity, and it must be done under the supervision of the State Department of Health.

All boats used in handling shellfish must be scrupulously clean. Only unpolluted water may be used for cleaning purposes In addition the fishermen must avoid polluting the waters, especially those over the shellfish growing areas.

There are also numerous requirements concerning the sanitary construction, equipment, and operation of shucking and packing plants. The requirements pertaining to construction deal with such items as lighting and ventilation, the construction and drainage of floors and storage bins, the protection against flies, the provision of sanitary toilets, and the provision of sanitary shucking benches and refrigerating rooms. An ample supply of running hot and cold water must also be provided. There must be sanitary hand-washing facilities, and the utensils must be of excellent quality, non-corrosive, impervious, and easily cleansed. Finally, all those engaged in handling shellfish must be examined to ascertain whether they are free of communicable diseases, and those individuals having had either typhoid fever or paratyphoid fever must have examinations made to ascertain whether or not they are carriers of these diseases. The regulations also require that the hands should be washed before starting work in the morning, after luncheon, and after using the toilet. In order to protect shucked shellfish against pollution it is required that clean, pure water of a given salinity be employed in washing. The temperature of refrigeration during storage or shipment may vary between 33° and 50° F.

Sterilization of shellfish. — In spite of the greater sanitary supervision in force today, the fact remains that it is impossible to safeguard a raw food supply like the oyster against pollution all the time. Furthermore, in certain areas where the waters are of doubtful sanitary quality, the opposition to the closing of these areas was so great that health authorities have been compelled to find another solution. Accordingly, the sterilization of oysters and clams by the use of chlorine has come into limited commercial use.

According to this procedure the shellfish are first cleansed in pure water and then introduced into a tank containing water at 60° F. to which a dose of chlorine equal to 0.5 part per million is added. At first the shellfish are irritated by the chlorine and do not suck in any water. During this time, however, the chlorine has an opportunity to destroy the bacteria on the outside of the oyster or clam. Later, when the chlorine has been used up to some extent and the shellfish are irritated no longer, they begin to cleanse themselves by taking in water. Since at moderate temperatures the oyster will filter through its gills approximately two gallons per hour, a considerable amount of water passes in and out of the oyster under these conditions. Furthermore, particles entering the shells of feeding oysters are passed to the stomach in less than 30 minutes, and ejected with the feces in less than 5 hours. Therefore, if the oysters are subjected to a chlorine water bath for six hours, they will have cleansed themselves entirely. This is done, and at the end of that time the oysters receive a second dose of chlorine, which destroys the bacteria that have been voided into the surrounding water. In this way the bacterial contamination of the oyster is either eliminated or greatly diminished.

Park and Krumwiede of the New York City Department of Health, have cast considerable doubt on the efficacy of this method as a means of eliminating typhoid infection in oysters. Oysters were infected artificially with living typhoid bacilli and treated with chlorinated water. These workers concluded that this treatment results in a marked diminution in the number of typhoid bacilli present but that even six successive treatments may not rid the oyster of the contaminating pathogens. The results indicate that the greatest reliance must still be placed on preventing the pollution of growing areas, rather than on the elimination of infection by disinfection or cleansing.

An epidemic of typhoid fever at Wesleyan University traced to infected oysters. — About October 20, 1894, several students were seized with a mild form of sickness accompanied by slight fever, which was not at first regarded as of much importance. The cases increased in number, some became more severe, and after about a week it became evident that a few, at least, were suffering from typical typhoid fever. New cases continued to appear until, by November 1, there were more than twenty. After November 1 the cases fell off, although one appeared as late as November 9.

In all there were twenty-five cases — twenty-three of well-defined typhoid, of which thirteen were very severe. Four of those attacked died.

Investigation was begun on November 4. Suspicion fell at first upon certain wells on the college campus, but these were excluded, chiefly on the ground that they were used by large numbers of townspeople as well as by college students, and that no typhoid had appeared among the townspeople.

No common bond was at first discovered among the victims of the disease, some of whom lived in different dormitories or club-houses, and others in private houses in the town. Nor did the persons affected board at the same tables. Besides, Wesleyan University is a coeducational institution, and it was early observed that the young women in the University — about fifty in number — were wholly exempt. Closer investigation showed that, with three exceptions, all the cases attacked belonged to three fraternities, and that within these some extremely potent source of infection had been active. Attention was thus concentrated upon these fraternities and their club-houses.

As is usual in such cases, the plumbing was carefully examined, and in two of the three houses it was found to be new and unexceptionable. Attention was next fixed upon the boarding clubs within the fraternities. The water, the ice, and the milk were all considered, but excluded as sources of infection, from the fact that they were shared in common by other fraternities or by the townspeople. Similar circumstances excluded cream, ice cream, butter, fruit, and other articles as probable sources of the disease. So difficult and far-reaching was the inquiry that it was even suggested that certain new foot-ball suits might have been infected, thus giving rise to the disease; but only a few of the men who had used the suits were found to be suffering from the disease, while several of the sick men had never touched them. There was also no evidence of secondary infection which could explain the outbreak, and particularly as there were no early cases of fever which could have served as the sources of such secondary cases. The first case appeared about October 20, and within a week from that time at least fifteen other cases had made their appearance.

These facts, of course, indicated plainly a common source of infection, and made it possible to believe that any of these was the source of all the others by ordinary contagion.

Moreover, there was a very small amount of typhoid in the city. The quotations following are taken from the report of Professor Conn mentioned above.

"In short, all the lines of investigation upon the relations of the students, the conditions of their fraternity houses, and the tables at the fraternity houses led to negative results, giving no point of common union between the three fraternities in question, which was not shared equally by the four other fraternities and the ladies in the college, and equally by the citizens in town."

A study of the dates on which the disease had appeared threw suspicion upon a series of fraternity suppers held at the society initiations of new members upon the 12th of October, and this suspicion was strengthened by the explanation which it appeared to offer of one of three cases which had appeared among members of the University not in any of the three fraternities. This person had attended the initiation banquet held by one of these three clubs, but had not boarded with them either before or afterward. Examination of the menu of the banquets excluded nearly all articles of food, such as water, ice, milk and cream, ice cream, fruit, and salad, as possible sources. The celery used in the salad was at first regarded as a source of possible danger. It had been bought from different dealers, but these dealers obtained it all from the same grower, and he had occasionally washed his celery in the water of the Connecticut River — a somewhat suspicious circumstance. Further inquiry, however, showed that the same dealer supplied nearly all the celery used in Middletown, and had consequently furnished hundreds of families from the same source.

As a result of the closest inquiry in regard to every article of food or drink used at the banquet, there were found to be only three common to the three suppers; namely, ham, a small amount of fruit, and raw oysters. The ham was readily excluded, both because it had been cooked and because the same dealer supplied other fraternities. Moreover, there was no reason to suppose that it had been contaminated. The fruit had been shared by other fraternities and by townspeople, and was therefore excluded.

"As soon as attention was turned to the oysters, however, the problems began to be solved at once. To those engaged in the investigation, one of the most striking phenomena was the quickness with which the puzzling questions were answered as soon as they were studied in the light of the oysters as a possible source of

contamination. It was found that the ladies in the college did not hold any special supper on the evening of October 12, nor eat raw oysters, either then or subsequently. It was found that of the other four fraternities, two did not use oysters at all at the initiation suppers; one obtained oysters from Hartford dealers, who obtained them from a different source than the Middletown dealers. The fourth used the oysters from the same source as the fraternities in question, but had used them cooked, while the three fraternities that had suffered from typhoid had eaten the oysters on the half-shell, and consequently raw. As soon as it was conceived that the oysters might be the cause of the trouble, one more of the exceptions above mentioned was explained, for one of the students belonging to another fraternity, who had suffered from a mild fever, stated that at about the time of the initiation banquets he had eaten raw oysters in the oyster dealer's store in town. This, of course, made it possible to bring this case within the same source of infection.

"Inquiry as to the use of the oysters in town revealed nothing which relieved the oysters from blame. Quite a number of families were supplied from the same lot of oysters, but so far as could be learned, only one family bought them to eat raw, and this family had subsequently moved from town and had been lost track of. Further facts concerning this case will be mentioned later. The attendants in the oyster dealer's store had probably eaten of the raw oysters, inasmuch as they did frequently do so, although they had no definite recollection of this particular lot. Neither of them had experienced any evil results. This, of course, is not surprising, since ordinarily not much more than ten per cent of those exposed to typhoid fever suffer from the exposure; and ever among the students at the banquet not quite one in four took the disease. If the people in town who ate the oysters had not generally cooked them before eating them, a larger number of cases would have been expected."

The oysters at the banquets were served on the half-shell as a course at the beginning of the supper. Careful inquiry was made as to how many persons had actually partaken of the oysters, and direct connection with the oysters was traced in all cases except one, this one student being unable to remember that he partook of them. He did, however, attend one of the banquets. The four who died were among those who partook of the oysters.

There were also present at the banquets a number of persons not students of the college. Among them were a number of alumni, and five students from Yale University. Reports were obtained from twenty-four of the alumni who ate of the oysters. Among them were several cases of slight illness, chills, diarrhea, weakness, and the like which appeared at about the same time that the typhoid appeared in Middletown. These may or may not have had some connection with the infection. In addition, four cases of genuine typhoid fever appeared, most of which had been pronounced to be typhoid before there was any knowledge of connection with cases at Wesleyan University. None were severe, but all appeared simultaneously with the cases at Wesleyan.

Of the five Yale students who attended the banquet, two developed typhoid fever, though at a rather late date.

These facts demonstrated that the cause of the infection was to be sought in the initiation suppers. The cessation of new cases at the end of four weeks and the appearance of at least six cases among visitors who came to the banquets and went away immediately afterward "are sufficient in themselves to indicate beyond peradventure that the initiation suppers are to be regarded as the source of infection. And when, further, it is seen that only one article of food or drink was used in common by these three societies, that was not used equally by the other fraternities in college and by people in town in general, it becomes equally certain that this one article of food must have been the source of infection.

"Inquiry showed that the oysters in question had been taken from deeper water in Long Island Sound, and had been brought [to Fair Haven, Connecticut] into the mouth of a creek known as Quinnipiac River, and allowed to lie in fresh or brackish water a day or two for fattening before they were taken out of the water and sent to the consumers. During this period of fattening the oysters are known to absorb fresh water and to swell up and become quite plump. The object of this treatment is partly to thus 'fatten' the oysters, and partly to wash them. Close to the oyster beds where this fattening occurs are the outlets of a number of private sewers. At a distance of some three hundred feet from the beds where the oysters were fattened was an outlet from a private sewer from a house in which were two cases of typhoid fever. The patients were a lady and her daughter. The cases were severe, the lady dying on the 21st of October, and the daughter convalesc-

ing only after five weeks' sickness. . . . The distance from the outlet of the sewer to the oyster ground was . . . between 250 and 300 feet. When the grounds were surveyed, it was further noticed that at the rising tide an eddy was found to be setting along the shore from the region of the sewer outlet up stream, in the direction of the oyster beds. This condition would plainly make it possible for typhoid contaminations from the sewer to be carried to the oysters.

"Examination as to the dates of the cases of typhoid occurring in the house on the sewer showed that the two persons in question were taken sick at just about the time that the oysters sent to Middletown were collected. The oysters were sent to Middletown on October 10, and the doctor was first called to these cases on October 11. The period of incubation of typhoid fever is known to be somewhat variable, and had certainly existed some time before the doctor was called. From the fact that when the doctor was called the lady was suffering from a severe chill and fever, is was plain that the conditions were such that infection through the sewer might naturally have taken place at least for several days prior to the period of the first visit of the doctor; for during this incubation period the persons may appear well, and yet the presence of the typhoid germs render their excreta infectious. Indeed, the danger might be even greater at this stage than subsequently, since as soon as the disease is plainly indicated nurses will be pretty sure to disinfect the excreta and thus diminish the danger. This would bring the time of possibility of infection at just about the period when the oysters sent to Middletown were collected."

Special investigations made by Dr. Charles J. Foote, of the Yale Medical School, showed that typhoid bacilli forced in between the shells of oysters taken from the creek were found alive and capable of growth at the end of forty-eight hours, and—"this is all that is required to account for the outbreak at Middletown."

In connection with an outbreak of typhoid fever at Amherst College at the same time as that of Wesleyan, it was learned that Fair Haven oysters had also been sent to Amherst. In the latter institution a similar banquet was held upon the same evening, October 12, at which raw oysters were served, and of six students who afterward suffered from typhoid fever all but one ate raw

oysters on or about that date. It was not discovered whether or not the oysters came from the same dealer in Fair Haven, but the suspicion was strong that such was the fact.

One of the most interesting and instructive circumstances connected with this epidemic remains to be stated. A young man whose home was in Boston, himself a student at Harvard University, came down with typhoid fever. His case at first seemed utterly inexplicable. It happened that his father was a physician and for a time no reasonable explanation could even be thought of. It proved, however, that about two weeks before he fell ill he had gone home with a classmate whose family lived in Middletown, and inquiry showed that he was attacked, after he had returned to his home in Boston, at precisely the same time as the Wesleyan students, and that he had eaten raw oysters while in Middletown. It further appeared that the oysters which he ate came from the same dealer as those with which the Wesleyan banquets were supplied, and that he had, in fact, partaken of the one lot which, as was mentioned above, had been sold by the Middletown dealer to a family in Middletown to be eaten raw.

A typhoid fever epidemic (affecting New York, Chicago, Washington, and other cities) caused by oyster-borne infection, 1924–1925. * — What will probably prove to be one of the most widespread and famous epidemics of typhoid fever due to the consumption of raw oysters occurred in the United States during the late fall and early winter months of 1924 and 1925 and affected the population of the middle Atlantic and north central states. While the epidemic was especially severe in New York, Chicago, and Washington, it also affected the cities of Rochester and Buffalo, N.Y.; Scranton and Pittsburgh, Penn.; Cincinnati, Ohio; and Detroit and Grand Rapids, Mich. To a lesser degree it also affected a few individuals in Providence and New Haven, who had been to New York and had partaken of raw oysters from the supply in question. The epidemic is the more remarkable because the responsible oysters — Bluepoints — came from a dealer in Great South Bay, near West Sayville, Long Island, N.Y., whose plant was equipped with unusually satisfactory methods of sewage disposal, and whose care in the handling of oysters was superior to the normal practice.

* L. L Lumsden, H E. Hasseltine, J P Leake, and M V. Veldee, *Supplement No. 50, U.S. Public Health Reports*, March 12, 1925.

The epidemic was investigated by the local health departments of the cities affected and particularly fine reports were issued by the New York and Chicago Health Departments. The U.S. Public Health Service investigators studied the question in most of the cities affected, and their report, from which this account is drawn, is a model of completeness, of scientific analysis, and of epidemiological procedure. It is interesting that after considering all the possible vehicles of infection, including the city water supplies in question, bottled waters, milk and cream, ice cream, butter, cheese, marketed bread and pastry, insanitary conditions in the home, association with typhoid patients, convalescents, carriers, uncooked vegetables such as celery, lettuce, radishes, and onions, and uncooked shellfish such as clams and oysters, the investigators of the U.S. Public Health Service came to the same conclusion independently, namely, that raw oysters were the responsible vehicle of infection in this epidemic. The epidemic was unusual also in that the cases affected came from the finest residential sections in each city, that many of them were wealthy or in very comfortable financial circumstances, that the people affected occupied superior professional or social positions in their communities, that children were not affected, that the age group most affected was between 20 and 34, that negroes were singularly free of the disease, that most of those affected were women who have a predilection for the smaller oyster of the Bluepoint type, that they had dined out in fashionable restaurants, hotels, or clubs during the incubation period prior to the onset of the epidemic, that most of the cases admitted eating raw oysters during this period, and that over 58 per cent of the cases in Washington, 82.5 per cent of the cases in Chicago, and 81.3 per cent of the cases in nine other cities ate Bluepoint oysters obtained from the same dealer in Long Island. The period of infection began about October 26, 1924 in Chicago and Washington, about seven days later in New York, and ended about December 20, 1924. Although it is impossible to state the exact number of cases resulting from this epidemic because of unreported, mild, and missed cases, it is estimated that for the area affected there were over 1,500 cases and 150 deaths in excess of the normal expectancy for the period under consideration.

The publicity following the recognition of the epidemic condition, due in part to its magnitude and to the prominence of the

people affected, naturally aroused popular apprehension concerning the safety of oysters, and caused a marked reduction in their sale, varying from 25 to 75 per cent for different producing areas, and almost 100 per cent for the lower New York Bay area. The financial loss to the oyster industry was large and the suffering resulting from the deprivation of wages among the thousands of persons dependent upon this industry for work was serious. The popular apprehension affected not only the shellfish industry, but also the scalefish industry, although the latter was not involved. It is of course impossible to estimate the magnitude of the suffering and loss experienced by those individuals who came down with typhoid fever, or the misery it brought to families where a death occurred.

Numerous individual case histories point unquestionably to the responsibility of the Bluepoint oysters from Great South Bay in Long Island. In Chicago, two sisters, one from Lafayette, Indiana, and married, the other a student at Northwestern University, held a reunion on November 11, 1924, while the husband was in the city on business, and while dining out in a popular restaurant had Bluepoint oysters, which subsequent investigation showed came from the dealer on Great South Bay. That evening the student sister returned to the University and the following day the married sister returned to her home. Both sisters subsequently came down with typhoid fever, the married one on November 21, and the student on November 23.

Another instance is that of a family of four adults living in Chicago who on November 30, 1924, went by automobile to Joliet, Ill., where they had dinner, after which they returned home. All ate the same kind of food except that three had Bluepoints on the half shell, while the fourth had to be satisfied with soup because the restaurant did not have enough oysters for all four. Twenty-four days later two members of the party who had eaten oysters came down with typhoid fever, and on investigation it was found that the oysters had been purchased from a dealer in Chicago who in turn had purchased them from the dealer in Great South Bay.

Still another case that may be cited occurred at a banquet for 700 people at one of the large New York hotels on November 18, 1924. Within a period of thirty days ten of those persons developed typhoid fever. At the dinner the guests ate at tables

accommodating from 6 to 20 people. Seven cases of typhoid fever were investigated. Four of these cases obtained their infection at one table which had accommodated 16 people. Of the 16 people who ate at this table, 6 did not eat oysters, and of the 10 who did, 5 developed typhoid fever within 30 days. In this case, too, the oysters had been obtained from the dealer in Great South Bay. As the number of people attending the banquet was large, the supply of oysters had been obtained from several dealers. This probably accounts for the limited number of cases that developed.

It is also of interest to note that some of the cases that developed typhoid fever during this epidemic had either had typhoid fever before or had been immunized against the disease. It would seem, therefore, that one attack of typhoid fever does not confer a lasting immunity, and it is a well-known fact that artificial immunity produced by inoculation results only in a temporary immunity, lasting usually about three years. It is obvious, therefore, that the control of typhoid fever cannot be accomplished by artificial immunization alone, but that it must be accompanied by flawless sanitary protection as well.

In spite of the overwhelming evidence pointing to the Bluepoint oysters from Great South Bay as the responsible vehicle of infection it has been impossible to ascertain how the infection actually occurred. It is known that typhoid fever was unusually prevalent in Islip, Long Island, the area in which West Sayville is located, during October and November, 1924. It is doubtful whether any of the sewage from shore found its way into the waters of Great South Bay, where the Bluepoint oysters had been floated at a depth of two or three feet below the surface. It is known, however, that the waters of the Great South Bay had been used by boats of various kinds, including oyster dredging boats, scale fishermen, and others. Some of these boats tied up at the wharf only about 20 yards from the oyster floats, and some of the pollution may have come from these sources. It is likely, too, that numerous visitors came to this wharf at night. In the opinion of the investigators of the U.S. Public Health Service, "it is hardly conceivable that some persons did not void their excreta into the water, especially at night, at points near the oyster floats." If this be true there is no question that the infection of the oysters could have occurred in this way. It is also

known that the advent of cold weather in the autumn of 1924 was considerably delayed, and that the oysters in the beds of Great South Bay probably did not reach an advanced stage of hibernation before November 15 or 20. It appears, therefore, that those oysters were "drinking" freely during the period involved, and it seems conceivable that some of the oysters in the beds and on the floats became infected from the excreta of the dredgers or of other persons on boats plying in those waters or tied up to the wharf of the dealer in question.

Fruits, vegetables, ice cream, etc., as vehicles of disease. — Inasmuch as any uncooked food material may be polluted, and, if eaten in this condition, may become the vehicle of disease, it is easy to see how berries, such as strawberries, grown and lying on earth which has been fertilized with night soil, or mulched with infected manure, or vegetables, such as lettuce, celery, radishes, onions, watercress, and the like, if eaten raw, or without adequate cleaning, may readily convey the germs of certain diseases to the consumer. On the other hand, raspberries, cherries, apples, grapes, and similar fruits not coming in actual contact with soil are likely to be seriously infected only by handling. There can be little doubt too that the common American practice of buying fruit at fruit-stands, or from passing venders on the streets or in railway trains, may be a possible means for the distribution of certain diseases. When the fruit shop is also the home of the vender's family, or when berries, cherries, apples, and the like are picked over by persons whose hands and whose personal habits may be far from clean, it is possible that such food materials may be the means for the dissemination of "sporadic" cases of communicable disease.

On the other hand it is reassuring to note that certain fruits, such as oranges and bananas, although usually eaten raw, are effectively protected by their skins, which are invariably rejected, leaving only the clean and sterile interior to be eaten. The modern practice of wrapping fruits in clean paper has also diminished the possibility of disease from these sources.

As to figs, dates, and similar preserved fruits, rich in sugar, it must not be overlooked that if these have been prepared by unclean or infected persons, they also may become vehicles of disease. Recently pasteurized dates have appeared on the market. The high sugar content in dates, figs, and similar preserved foods

is doubtless a great aid in the elimination of the pathogenic bacteria that may be present.

The dangers connected with the consumption of ices and ice creams are far less today than before the almost universal application of pasteurization in their manufacture. It must be admitted, moreover, that the ice, the water, and especially the milk, used in ices or ice creams, may be sources of disease if these come from objectionable sources or are not rendered safe by preliminary treatment.

The sanitary significance of cookery. — Nothing is more certain in sanitary science than that cookery, which by the use of heat destroys parasites (including bacteria), is of the very highest hygienic value. If we may accept Charles Lamb's celebrated account of its discovery and general introduction, these were due more to the appetizing flavors which it develops than to anything else. Today, however, the sanitarian recognizes that important as are the flavors developed by cooking in stimulating appetite and creating or arousing a keen relish for food, they are of but minor consequence as compared with the importance of freeing roast pig and similar foods from possible parasites such as Trichina, or tapeworms. Writers on the physiology of cookery do not usually dwell sufficiently upon this aspect of the subject. They are accustomed, rather, to point to the greater digestibility of starches, meats, and fats when these are properly prepared for internal digestion by the external digestion (cookery) of the kitchen. They emphasize also the improved flavors developed, which arouse the appetite and stimulate the powers of digestion. These are unquestionably of great importance; but probably far more important in the history of the race has been the fact that by fire, food is largely purified from living parasites and other agents of infection. The great sanitary achievement of the nineteenth and twentieth centuries has been the sanitating of the intestinal tract of man. In its accomplishment, cooking and the application of heat under scientific control have played significant rôles. In the case of water supplies, where cooking could not be employed, the desired result has been obtained by filtration and disinfection.

CHAPTER XVI

THE PREVENTION AND INHIBITION OF INFECTION, DECOMPOSITION, AND DECAY

Asepsis, or the prevention of infection by exclusion. — It has already been stated in a previous chapter that for the genesis of communicable disease two factors at least are necessary; namely, first, an infectious substance, material, or element, ordinarily a microörganism; and, second, a susceptible subject. Communicable disease in its transmission or distribution thus represents one phase of the eternal struggle for existence, or that interplay with the environment which is the fundamental phenomenon of life. On the part of the organism attacked, it represents a phase in that continuous attempt at adjustment of internal to external relations which has been well defined as a leading characteristic of the life process. It will not do to assume that the cause of disease resides either alone or chiefly in the infectious element or in the organism attacked. The true cause of disease is found in the cooperation of both factors, the infectious element and the susceptible organism. It cannot be denied, however, that in the common use of the word "cause," it is the aggressor rather than the defendant that is normally considered; and nothing is clearer than the fact that if the infectious element can be successfully excluded or warded off, the disease, which might otherwise appear, can be avoided.

Modern surgery is the best possible example of the beneficent results of this kind of procedure. Before any serious operation upon the internal portions of the organism is undertaken, the parts upon which the incision is to be made are carefully cleaned, and even sterilized, with the sole object of excluding putrefactive and pathogenic bacteria. All knives and other instruments, all ligatures and similar appliances, are carefully freed by heat or by disinfectants from the organisms capable of producing sepsis, putrefaction or disease, and the most extraordinary pains are taken to exclude all microorganisms as completely as possible. The hands of the surgeon are made surgically "sterile," and are further safeguarded by means of sterile rubber gloves. Even the air of the

operating room may be made comparatively free of bacteria by washing or filtration. Surgery of this kind is rightly called "aseptic," and although doubtless in many cases it is not absolutely successful in excluding every microorganism, it is nevertheless sufficiently so in the great majority of cases to insure the wonderful success which attends modern surgical operations.

Aseptic surgery has been referred to in an earlier chapter as "sanitary" surgery, and the justice of this appellation will be perceived when it is demonstrated that precisely the same kind of exclusion is sought for in the larger procedures of the public health, as for example, when a water supply is protected from the germs of disease by exclusion. The life of the community may, in theory at least, be protected by the mere exclusion of pathogenic microorganisms from water supplies, milk supplies, air supplies, and food supplies. Since this is difficult of permanent attainment in practice, resort must be had to the various processes of purification already described.

Quarantine and isolation. — It is the recognition that prevention is better than cure which has led even uncivilized peoples instinctively to the endeavor to ward off disease by the exclusion of suspected persons, or by their detention at the frontier, until time shall have demonstrated whether or not they are vehicles of infection. The word "quarantine" is in itself a witness to the custom of detention, which in former times was sometimes forty days. Modern sanitary science has tended to show that quarantine, or the attempt of communities to protect themselves by the exclusion of human beings and merchandise which are possible vehicles of disease, is generally only an imperfect method of exclusion. There can be no question, however, as to the legitimacy of the fundamental principle involved.

With the increasing evidence of the difficulty of securing freedom from communicable disease by practising the old form of frontier quarantine, a modified form of quarantine, known as "isolation" has come into wider use. Isolation is essentially local quarantine, in which the person or merchandise suspected of being a vehicle of disease is separated or isolated from all other persons or articles of merchandise until the danger shall have passed. Practically this method of quarantine is more certain and successful, and it interferes far less with the ordinary conduct of commercial and civil life. It is therefore less subject to the usual temptations to elude,

evade, or disobey the underlying regulations. Everything depends, obviously, upon the thoroughness with which the exclusion is carried out, and on the thoroughness with which the law is enforced and obeyed. No one can doubt however that in special cases, such as the transmission of disease from one country to another through the medium of ships and the reservoirs of infection they may be carrying, that through their quarantine, inspection, and fumigation on arrival in well-guarded harbors such as New York, Boston, New Orleans, or San Francisco, it is still possible to effect important measures of protection with immense advantage to the public health.

Immunity, or the prevention of infection by insusceptibility. — Insusceptibility to disease appears to be in many cases very largely a matter of physiological vigor, *i.e.*, vital resistance and robust living. There can be but little question that individuals of strong constitution, well fed, well housed, well trained physically, and free from corroding care, anxiety, trouble, overwork, want of sleep, and similar depressing influences, are materially strengthened in their powers of resistance to disease. These matters are of fundamental importance to the public health, and the student of sanitary science must alway bear in mind the significance of the conditions favoring the most perfect operation of the animal organism. Overcrowding, overwork, overexcitement, underfeeding, undersleeping, underexercise — in short, all the conditions which tend to remove the organism from the normal in physical vigor — tend to the diminution of vital resistance and to the increase of susceptibility to disease. They are to be avoided as unwholesome and unsanitary, while normal, happy, vigorous, physical life is to be encouraged as probably the most fundamental and far-reaching of all sanitary measures tending to promote the public health.

Meantime, although complete immunity by artificial methods is not in sight, some steps toward it have been taken, at least in the case of certain diseases; and although these have been dwelt upon already to some extent, we may refer to them again at this point.

Insusceptibility artificially produced by inoculation. — One of the earliest attempts, if not the earliest, to influence directly the degree of susceptibility of the organism to a communicable disease was that of inoculation for smallpox. The objections to inoculation, however, were great; for although usually those inoculated

had the disease in a relatively mild form, occasionally the severest symptoms ensued, and disfiguration was not uncommon. Moreover, as the method was essentially one of cultivation of the disease, those inoculated became veritable centers of infection; and on the whole, while benefiting individual cases, the practice tended to spread the disease and to increase the general mortality. It was gradually displaced after Jenner's discovery of vaccination by that far safer method of producing insusceptibility, and in 1840 an act of Parliament rendered smallpox inoculation unlawful in England.

Insusceptibility artificially produced by that variety of inoculation known as vaccination. — Introduced by Jenner at the end of the eighteenth century and improved and extended by his successors, vaccination is today the principal weapon employed by the human race in its warfare with one of the most loathsome, and formerly one of the most dreaded, of all communicable diseases. Its practice is amply justified by experience, for it has been conclusively proved that persons successfully vaccinated are for a longer or shorter time insusceptible to smallpox inoculation.

The theory of vaccination depends upon the fact that comparative immunity appears to be produced in a vaccinated person by causing it to undergo a mild disease — cowpox — the recovery from which leaves the individual immune to virulent smallpox.

Some authorities have suggested that the comparative freedom of the most highly civilized peoples from smallpox is due in part to greater cleanliness and the improvement in general sanitary conditions accomplished since 1880. Resting chiefly upon this thesis, many people, known as anti-vaccinationists, deny altogether the efficiency of vaccination, and by dwelling upon the dangers of impure vaccine, and the possibility of introducing the germs of other diseases into the organism, have persistently objected to compulsory vaccination. The improvement in method and the scrupulous care used in the preparation of smallpox vaccine have eliminated the basis of this argument, and the majority of students and dispassionate observers, while allowing certain weight to these objections, nevertheless firmly believe that freedom from smallpox in vaccinated peoples at the present time is due chiefly to the almost universal practice of vaccination. In a disease so readily communicable as smallpox is, it is even likely that the extraordinary development of means of travel, and hence of the spread of disease, would

actually have caused an increase of smallpox, in spite of the general improvement in sanitary conditions, had it not been for the art of vaccination.

Nineteenth century progress in the art of inoculation and vaccination. — The applications of pure science usually follow close upon the heels of discovery, and long before the full establishment of bacteriology steps had been taken to modify and control the action of bacteria in communicable disease.

As early as 1880 Pasteur, reflecting upon the fact that smallpox must be considered to be a communicable disease, perceived that a reasonable theory of vaccination may be that somehow the germ of smallpox has been modified in the cow and rendered weak or "attenuated," so that when it was introduced into the human body it no longer was able to exhibit its former virulence. Filled with this idea, he accordingly undertook to produce a corresponding weakening or "attenuation" in the germs of certain common diseases such as chicken cholera and anthrax. In this attempt, in 1880, he met with surprising success; and it will be well worth while to note at this point an account of a public test of his work upon splenic fever vaccination which has been vividly portrayed by his son-in-law, M. Radot.*

A public demonstration by Pasteur of the possibility of protective inoculation of certain of the lower animals against anthrax or splenic fever. — "It was on February 28, 1881, that Pasteur communicated to the Academy of Sciences, in his own name and in those of his two fellow-workers, the exposition of his great discovery. Loud applause burst forth with patriotic joy and pride. And yet so marvellous were the results that some colleagues could not help saying, 'There is a little romance in all this.' All this reminds one, in fact, of what the alchemist of Lesage did to the demons which annoyed him. He shut them up in little bottles, well corked, and so kept them imprisoned and inoffensive. Pasteur shut up in glass bulbs a whole world of microbes, with all sorts of varieties which he cultivated at will. Virulences, attenuated or terrible, diseases, benign or deadly, he could offer all.

"Hardly had the journals published the *compte rendu* of his communication, when the President of the Society of Agriculture in Melun, M. le Baron de la Rochette, came, in the name of the

* *Louis Pasteur: His Life and Labors*, by Vallery-Radot, from the French, by Lady Claud Hamilton, New York, Appleton, 1885.

society, to invite Pasteur to make a public experiment of splenic fever vaccination.

"Pasteur accepted. On April 28 a sort of convention was entered into between him and the society. The society agreed to place at the disposal of Pasteur and his two young assistants, Chamberland and Roux, sixty sheep. Ten of these sheep were not to receive any treatment; twenty-five were to be subjected to two vaccinal inoculations at intervals of from twelve to fifteen days, by two vaccines of unequal strength. Some days later these twenty-five sheep, as well as the twenty-five remaining ones, were to be inoculated with the virus of virulent splenic fever. A similar experiment was to be made upon ten cows. Six were to be vaccinated, four not vaccinated; and the ten cows were afterward, on the same day as the fifty sheep, to receive inoculation from a very virulent virus.

"Pasteur affirmed that the twenty-five sheep which had not been vaccinated would perish, while the twenty-five vaccinated ones would resist the very virulent virus; that the six vaccinated cows would not take the disease, while the four which had not been vaccinated, even if they did not die, would at least be extremely ill. . . .

"The experiments began on May 5, 1881, at four kilometres' distance from Melun, in a farm of the commune of Pouilly-le-Fort, belonging to a veterinary doctor, M. Rossignol, Secretary-general of the Society of Melun. At the desire of the Society of Agriculture, a goat had been substituted for one of the twenty-five sheep of the first lot. On the 5th of May they inoculated, by means of the little syringe of Pravaz — that which is used in all hypodermic injections — twenty-four sheep, the goat and six cows with five drops of an attenuated splenic virus. . . .

"On May 31 very virulent inoculation was effected. Veterinary doctors, inquisitive people and agriculturists formed a crowd round this little flock. The thirty-one vaccinated subjects awaiting the terrible trial stood side by side with the twenty-five sheep and the four cows, which awaited also their first turn of virulent inoculation. Upon the proposal of a veterinary doctor, who disguised his scepticism under the expressed desire to render the trials more comparative, they inoculated alternately a vaccinated and a non-vaccinated animal. A meeting was then arranged by Pasteur and all other persons present for Thursday, June 2,

thus allowing an interval of forty-eight hours after the virulent inoculation.

"More than two hundred persons met that day at Melun. The Prefect of Seine-et-Marne, M. Patinot, senators, general counsellors, journalists, a great number of doctors, of veterinary surgeons and farmers; those who believed, and those who doubted, came, impatient for the result. On their arrival at the farm of Pouilly-le-Fort, they could not repress a shout of admiration. Out of the twenty-five sheep which had not been vaccinated, twenty-one were dead; the goat was also dead; two other sheep were dying, and the last, already smitten, was certain to die that very evening. The non-vaccinated cows had all voluminous swellings at the point of inoculation, behind the shoulder. The fever was intense, and they had no longer strength to eat. The vaccinated sheep were in full health and gayety. The vaccinated cows showed no tumor; they had not even suffered an elevation of temperature, and they continued to eat quietly.

"There was a burst of enthusiasm at these truly marvellous results. The veterinary surgeons especially, who had received with entire incredulity the anticipations recorded in the programme of the experiments, who in their conversations and in their journals had declared very loudly that it was difficult to believe in the possibility of preparing a vaccine capable of triumphing over such deadly diseases as fowl cholera and splenic fever, could not recover from their surprise.. They examined the dead, they felt the living. . . .

"Having suddenly become fervent apostles of the new doctrine, the veterinary surgeons went about proclaiming everywhere what they had seen. One of those who had been the most sceptical carried his proselytizing zeal to such a point that he wished to inoculate himself. He did so with the two first vaccines, without other accident than a slight fever. It required all the efforts of his family to prevent him from inoculating himself with the most virulent virus.

"An extraordinary movement was everywhere produced in favor of vaccination. A great number of agricultural societies wished to repeat the celebrated experiment of Pouilly-le-Fort. The breeders of cattle overwhelmed Pasteur with applications for vaccine. Pasteur was obliged to start a small manufactory for the preparation of these vaccines, in the Rue Vauquelin, a few paces

from his laboratory. At the end of the year 1881 he had already vaccinated 33,946 animals. This number was composed of 33,550 sheep, 1254 oxen, 142 horses. In 1882 the number of animals vaccinated amounted to 399,102 which included 47,000 oxen and 2000 horses. In 1883, 100,000 animals were added to the total of 1882."

These experiments drew universal attention to the subjects of immunity and susceptibility. Pasteur's experiments, moreover, had abundantly demonstrated that immunity to anthrax could be artificially produced. These ideas coincided with the suggestion that bacteria give off or contain poisons — toxins — for it was possible to see how, either by reducing the virulence of the toxins, or by accustoming the organism to them, gradually, insusceptibility or virtual immunity might be produced.

Insusceptibility produced by inoculation of biological products. — To discuss all aspects of immunity, interesting though that would be, would carry us too far into the domain of bacteriology and medicine. Suffice it to say that in many instances studies in immunity have already borne the richest fruit. Thanks to Behring, Roux, and others, it is now possible to produce at will not only the toxin of diphtheria, but also the antidote to this poison, diphtheria "antitoxin." The chain of reasoning and the experimental work involved in this discovery constitute one of the most beautiful examples of patient scientific work in the whole history of experimental medicine and sanitary science. It is now generally admitted that the antitoxin of diphtheria may be employed successfully not only to reënforce the organism already suffering from the disease, but also as a prophylactic or means of prevention in others who are susceptible and who have been exposed to the disease.

In addition, toxin-antitoxin, and more recently, toxoid, have been developed to immunize healthy but susceptible individuals against diphtheria. An antitoxin for scarlet fever has also been developed in recent years, following the isolation of the cause of that disease by Drs. George and Gladys Dick. Specific biological agents have also been developed to test the susceptibility of an individual against diphtheria and scarlet fever. By the use of saline suspensions of the dead bacteria of certain specific diseases such as typhoid fever, dysentery, and cholera, it has been possible to protect whole armies and large portions of the civilian population

against those dreaded intestinal diseases. One other triumph must be mentioned — also achieved by Pasteur — although there are many others that could be included, and that is the successful protection of humans bitten by rabid dogs against the dread disease, rabies, by inoculations with the properly prepared, desiccated spinal cord of a rabbit, which had been infected with the rabies virus.

Antisepsis and the prevention of infection. — Theoretically it should be possible to inhibit or check the progress of any communicable disease within the organism by the use of substances capable of interfering with or inhibiting the growth and multiplication of the microorganisms involved. In practice, however, to do this is far more difficult than might be expected, so that the prevention of infection by exclusion (*asepsis*), the prevention of infection by insusceptibility (*immunity*, natural or acquired), and *external disinfection*, or the destruction and removal of infection from the environment — are infinitely more valuable methods of procedure in our present state of knowledge in sanitary science. The reason for this is to be found partly in the difficulty of bringing to bear upon microorganisms, scattered throughout masses of tissue or widely distributed in ducts or canals, agents capable of inhibiting or checking their activity, but chiefly in the fact that such agents as we now have available are almost invariably harmful to the organism which it is desired to benefit. It is a fact which should never be forgotten that microorganisms capable of producing disease, although removed from man and the higher animals by the whole length of the animal and vegetable kingdoms, are, nevertheless, composed of protoplasm, very similar in its chemical and physical properties to that which constitutes the basis of the higher forms. Broadly speaking there is a sensitiveness to inhibiting agents in the one class of organisms similar to that in the other.

Already, however, specific chemical agents have been developed for the effective treatment of several communicable diseases where antitoxins or vaccines are not available. Notable among these are the use of quinin against malaria, arsphenamine against syphilis, and silver nitrate in the eyes of the newborn against ophthalmia neonatorum or gonococcic blindness of the newborn. The field of chemo-therapy is still new and relatively unexplored. It is not beyond the range of possibility, therefore, that as a result of

scientific research and a better understanding of the physics and chemistry of microbial metabolism numerous specific chemical agents will be developed, capable of being administered into the body — orally, intravenously, or otherwise — without injury to the individual, which will be effective in eliminating the agent or its products responsible for specific diseases. The work of Paul Ehrlich in developing "606" or salvarsan as an antidote for syphilis is a case in point. It must rank with the great achievements in biochemistry and be but a forerunner of others yet to come. The recent work on the biochemistry of the tubercle bacillus and the pneumococcus, and the development of bacteriophage are additional illustrations. The last few years have also witnessed the development of new and powerful chemical disinfectants reputed to be entirely harmless to the human organism, even when administered internally. Great progress in biochemistry may be confidently expected in this direction, thus linking preventive medicine and curative medicine.

Agents capable of checking or inhibiting the growth of microorganisms, in the manner suggested above, but without necessarily killing them, are known as "antiseptics," and the process of such inhibition as "antisepsis." Obviously all disinfectants or destroyers of infection are also antiseptics when applied in more limited quantity or for a short enough time; but the reverse is not true, for many antiseptics are not necessarily disinfectants. In the general use of the term, a disinfectant is an agent, usually chemical, capable of destroying the microörganism or cause of an infection.

It has been proposed to introduce into the alimentary canal in certain diseases agents capable of checking the progress or multiplication of the organisms of infectious disease, and which are at the same time harmless to the alimentary tissues. This procedure, if accomplished, might properly be described as intestinal antisepsis. Several dyes, neutral acriflavine, crystal violet, gentian violet, and malachite green, have been effective agents against the bacteria of the intestinal tract. While the subject of intestinal antisepsis is worthy of continued investigation, there is always the drawback of possible damage to the living cells in the intestinal mucosa. The concentration and dose of the antiseptic must be borne in mind constantly. While the use of intestinal antiseptics may have a palliative effect in combating intestinal disease it is

doubtful whether they can have complete therapeutic properties without injury to the host. At least much further proof of their effectiveness and inocuous quality is needed.

In the use of fermented milks, like acidophilus milk and bulgaricus milk, the aim is to replace the putrefactive bacteria of the intestine which produce presumably toxic protein decomposition products by the more benign fermentative bacteria like Bacillus acidophilus or Bacillus bulgaricus which do not produce such toxic end-products, and inhibit putrefactive changes through acid production. Metchnikoff believed that premature death could often be prevented in this way. It is extremely doubtful, however, aside from the psychological value of the treatment and the nutritive value of the milk, whether the theory has any firm basis of scientific fact. Surely the intestinal flora can be regulated to some extent by modification of the diet but it is not entirely certain that one can secure the desired results simply by ingestion of billions of bacteria which may or may not survive.

The control of infection in decomposition and decay. — From the sanitary point of view decomposition and decay must almost invariably be regarded with suspicion, although they are normal processes in nature and often of high usefulness in the arts and industries of daily life. The reason for this suspicion is that they are usually effected by bacteria or other microorganisms with which those of infections may be readily associated. Moreover, the chemical products of decomposition and decay are sometimes objectionable or even dangerous so that the race in its long experience has properly enough come to regard them as potentially dangerous. For protection of food and food products against putrefactive change for the limited periods during which they are ordinarily kept, application of such inhibitants as cold, dryness, certain weak acids, concentrated sugars, and salt, is effectively employed. To be effective, however, the action of the inhibitant must be continuous. Partial sterilization, by heat, *i.e.*, the destruction of the less resistant non-sporing organisms, is also temporarily useful and safe as is observed in the pasteurization of milk. For foods to be kept for long periods actual or complete sterilization is also sometimes employed, as in the canning industry.

Sanitary aspects of refrigeration and cold storage. — Probably the most widely used inhibitant is simple cold. Even before the introduction of the use of ice, low temperatures were recognized

as prolonging the " keeping " quality of foods, and they were regularly put in cool cellars, lowered into wells, or covered with wet cloths and exposed to wind in shady places so that the cooling effect of evaporation might be secured. Since the last quarter of the nineteenth century the use of ice, at least in America, has become a commonplace practice. Today (1934) refrigeration is accomplished on a large scale in industry and the home, by mechanical methods, with the aid of gas or electricity, and some refrigerant like sulphur dioxide, ammonia, or some of the newly developed chemical compounds which can be employed for this purpose. Solid carbon dioxide, " dry ice," is also being used effectively for refrigeration, especially where foods must be kept cold in retail shops, or in transit by trucks or other vehicles.

Nearly all large cities have huge structures known as " cold-storage " warehouses, in which vast quantities of perishable materials are successfully subjected to the inhibiting action of low temperatures. The equipment of the best types is elaborate and costly, for they must be substantially and carefully built, furnished with efficient ammonia machines or similar appliances for the production of cold, and with adequate ventilation. Cold brines for chilling room purposes is distributed to markets through pipes from central stations, very much as steam is circulated in winter for the heating of apartments. Such systems have real sanitary value, for pathogenic microbes do not multiply at low temperatures — below 40° F. — and as a matter of fact, tend to die out. Those microbes responsible for putrefactive change may increase, slowly in some instances but in general without adverse results. With the advent of mechanical refrigeration lower temperatures and therefore more effective refrigeration can be readily obtained than is possible in the ordinary icebox, especially during the summer months when food spoilage occurs very readily and food infections more frequently. Commercial development in the " quick freezing " of foods has also been accomplished by mechanical methods with the resulting preservation of the original flavor and texture of the fresh food, and effective protection against spoilage. The application of low temperatures to food has resulted not only in diminishing food infections and spoilage, but it has equalized the availability of food regardless of season. With the aid of refrigeration man may now travel to the most distant points on the earth and be assured a constant supply of fresh foods.

Sanitary aspects of desiccation, drying, evaporation. — A widely used and primitive method of food-preserving for meats, fruits, and various other food materials, is the process called "drying." It is obvious that this method if efficiently carried out possesses important sanitary advantages, as most of the microorganisms of disease and putrefaction, with the exception of a few spore formers, do not readily withstand prolonged desiccation. Of course the foods must be maintained in a dry atmosphere and protected from dust. It is possible that some of the vegetative germs may not perish — but they are so diminished in number, or become so attenuated, that they lose their sanitary significance. Whatever danger still remains is eliminated entirely, since, with the exception of some fruits, most dried foods, such as fish, apricots, dried beef, dried beans, and other vegetables, etc., are rarely eaten without having been first heated or thoroughly cooked.

Sanitary aspects of smoking foods. — A similar line of reasoning applies to the use of smoked foods, such as fish, beef, or hams. In this case the process of water removal is accompanied by exposure to smoke, or to treatment with salts containing the products of wood smoke, so that whatever antiseptic or disinfecting effects may reside in smoke are added to those of desiccation. There is reason to believe that smoke possesses some disinfecting properties due to the cresylic compounds or other materials which it contains, and therefore the process must be regarded as having sanitary significance, as well as producing a modification of flavor.

Since smoked foods are eaten frequently without cookery of any kind their treatment is of special interest to the sanitarian. In all probability the processes to which smoked foods have been subjected, while not such as to produce complete disinfection, are nevertheless sufficient to destroy most superficial disease germs which may be present. If, nevertheless, after having been smoked and dried, such foods are handled by unclean persons and then eaten raw, they constitute a source of danger similar to that which resides in all raw and manipulated foods.

Of preserving. — The process known as preserving is one in which decomposition is arrested or prevented by the use of sugar syrups or other substances of considerable density which furnish an unfavorable environment to the organisms of decomposition and decay. The inhibition of bacteria in certain concentrations of sugar or salt is accomplished by the phenomenon of plasmolysis,

a process which results in the removal of most of the water from the bacterial cell.

Of canning. — The art of canning when properly carried out is based on the total destruction of all microörganisms present, or sterilization. Being hermetically sealed, reinfection is impossible unless the container is defective. It sometimes happens, nevertheless, that canned foods are only imperfectly sterilized, and when this is the case such foods may show fermentation or decomposition. In such cases, however, the germs of putrefaction will doubtless have made the contents of such cans unattractive or repulsive, so that in reality there is slight danger of transmitting infection or disease through canned foods.

Of pickling. — Another method of securing disinfection and antisepsis is the art of pickling, or the preservation of foods in brines, or vinegar. In this case while the antiseptics employed are sufficient to prevent decomposition and decay, it is unlikely that thorough sterilization or disinfection is always brought about, and there is a bare possibility that disease, through infected foods thus preserved, may be caused in this way.

Sanitary aspects of pasteurizing. — A process now much used for food-preserving is that form of partial sterilization by heat known as pasteurizing. This has for many years been much employed in the dairy industry in the pasteurizing of milk and of cream. It is of immense importance as a practical means of food-preserving, and from the standpoint of sanitary science, if carefully conducted, is also of great value.

CHAPTER XVII

THE DESTRUCTION OR REMOVAL OF INFECTION. DISINFECTION AND DISINFECTANTS

Definitions. — Disinfection is the term applied to any process by which the infectious properties of any object are removed or destroyed, and a disinfectant is any agent or factor by which this process may be brought about. Obviously disinfection may be either partial or complete, but the term is usually applied only when the process, whatever it may be, is completely effective. Disinfection differs from asepsis in the fact that the presence of infection is assumed to exist in the material to be disinfected, while in asepsis the endeavor is made to prevent or forestall infection. In other words, *disinfection* cures or corrects an infectious condition, while *asepsis* avoids and *antisepsis* inhibits infection. All disinfectants are naturally antiseptics, but antiseptics as we ordinarily use the term are not disinfectants. Obviously a disinfectant when diluted, or allowed to act for a brief period only, may function as an antiseptic; while an antiseptic, working for a long time or in unusual concentration, may eventually weaken the organism to the point of death, but would not conform to the definitions of a disinfectant. Antisepsis is of value largely in the prevention of changes due to microbes in solutions, in technical preparations and some food products, while disinfection other than that produced by heat and light is too poisonous or drastic for this purpose. In general, the term is usually applied to the purification of substances (clothing, houses, hands, wounds, etc.) from the germs of disease, and only rarely to the arts of food-preserving.

Disinfection by chemical agencies. — Fire is from every point of view the most valuable and effective disinfectant. The disinfection of food by cookery is perhaps the most valuable part of that process, and the experience of the race has taught that it is no less effective in other directions. Infected houses, infected bedding, infected clothing, are readily disinfected by fire or by live steam. Fire has always been, and probably will always continue to be,

the simplest, the readiest, and the most effective of all disinfectants.

Next in readiness and efficiency to fire as a disinfectant come the chemical poisons, such as corrosive sublimate (mercuric chloride), carbolic acid, the cresols, strong mineral acids and alkalies, sulphurous acid, formaldehyde, the halogens such as chlorine and iodine, certain salts like silver nitrate, copper sulphate, and zinc sulphate, hypochlorite of lime, milk of lime, and a host of newer chemical agents such as mercurochrome, especially in alcoholic solution, hexylresorcinol, metaphen, acriflavine, and others. These, by producing coagulation, oxidation, or new chemical compounds within the pathogenic organisms, so alter their chemical composition as to destroy their vital activity. In some cases, owing to special protective conditions which surround the infectious elements, such as the presence of organic matter in various forms, these poisons may become for a longer or shorter time more or less ineffective — and this state of affairs is probably common, and must be taken into consideration when studying the effectiveness of any disinfectant. It is also important not to place too much confidence on new or widely advertised disinfectants until their efficacy has been demonstrated by reliable scientific investigations.

Disinfection by physical agencies. — Closely analogous to the effects just described as due to fire and poisons are those which come from heat, a moderate degree of temperature being favorable to the continued life of organized infectious elements, but higher temperatures being more and more prejudicial to them. In general it may be stated that the temperature of boiling water, *i.e.*, 100° C., destroys most ordinary infectious materials by causing a chemical coagulation of the protoplasm; but it is often necessary to use higher temperatures to sterilize canned foods, for example, because of the possible presence of spore-forming bacteria. These organisms are especially resistant to heat, so that at a temperature of 100° C. destruction occurs only after prolonged exposure often of hours' duration. This greater resistance to heat is probably due to the combination of the slight protection afforded by the spore membrane, and by the more concentrated and dried protoplasm present in spores. Cold is less effective than heat as a disinfectant, although, as we have seen, its inhibitory power is marked and constantly utilized in daily life. Nevertheless the evidence pre-

sented in the bacterial purification of ice in freezing and in the reduction of bacteria found in foods stored at low temperatures over a long period of time, indicates that cold does, in fact, play a part, not only as an antiseptic, but also as a slowly acting disinfectant.

Another significant agent of disinfection is dryness. Living things require not only a favorable temperature, but also considerable moisture; and a high degree, or a long period of dryness contributes to the destruction of germ life. It is doubtful, however, whether natural dryness, *i.e.*, air drying as it occurs in nature, is a perfect disinfectant. There is reason to believe that precisely as prolonged moderate heat is required in order to destroy infection, so prolonged dryness is required unless it be brought about thoroughly and rapidly by artificial means.

One of the most interesting discoveries in bacteriology is that which showed the germicidal efficiency of light. It had been known for some time to botanists that insolation, or the exposure of living organs or organisms to the light, appeared to bring about a relatively rapid disintegration of their protoplasm. It is now well known that sunlight has a marked germicidal power, and is, therefore, an important disinfectant, especially in summer when the sun's rays are most intense and contain the maximum amount of ultraviolet rays.

The germicidal effect of sunlight is due to the action of the violet and especially the ultraviolet rays of the spectrum. These rays are of short wave length, although they are by no means as short as the X-rays, or radium rays, or the so-called cosmic rays. They have been used in the disinfection of water, and in the treatment of certain skin diseases. They are also of value in forming the anti-rachitic vitamin in the animal body, which is necessary for building bone tissue and for the prevention of rickets. It is not surprising, therefore, to find that rickets is practically an unknown disease in tropical countries like Puerto Rico, in spite of the prevailing malnourishment among the children of the poor.

X-rays are also germicidal, but the time of exposure necessary is rather long, so that for practical purposes they are of little value in disinfection.

Much has been expected from electricity as a disinfectant; but the experimental evidence thus far available does not seem to justify any great expectations in this direction. Infectious organ-

isms are themselves so similar, in their electrical resistance, to the human body, or the foods in or upon which they may be, that it does not at present seem likely that such germs will be destroyed by electric currents, without, at the same time, destroying their hosts, or altering the media upon which they may reside. Where the electric current has proved effective as a germicidal agent, it has been due to the formation of acids or alkalies when a direct current was employed, or to an elevation in temperature sufficient to kill bacteria, when an alternating current was used.

Disinfection by filtration. — The processes thus far described bring about disinfection for the most part by the *destruction* of the infectious elements. The definitions given at the beginning of this chapter, however, imply the possibility of removing the bacteria without their destruction; and such processes are, in fact, conceivable and practicable.

Such a physical separation or removal may take place, for example, in filtration. If a drinking water is made to pass through a material the pores of which are so fine as to be impassable by the infectious elements, while yet permeable to the water, then, such mechanical filtration or removal of the bacteria is plainly one form of disinfection. Various biological products, such as diphtheria antitoxin, which cannot be sterilized by the application of heat without altering its chemical state, are sterilized by filtration through earthenware or porcelain filters, often spoken of as Berkfeld filters.

Disinfection by mechanical means. — Another form of disinfection by removal is that effected by gravity. A polluted water brought to rest and stored may be purified, in part, by sedimentation. Since the infectious elements and bacteria in general are heavier than water, and are often attached to heavier suspended particles, they may be drawn down by gravity and deposited upon the mud at the bottom of a reservoir, lake, or other body of quiet water. Such sedimentation undoubtedly contributes to a genuine disinfection of a water supply.

It also has been demonstrated in the laboratory that bacteria can be destroyed mechanically through disintegration resulting from vigorous and prolonged agitation. The use of excessively high pressures — 25,000 to 50,000 pounds per square inch — is also apparently successful in the destruction of germ life. Furthermore, in 1931, evidence was presented at the New Orleans

meeting of the American Association for the Advancement of Science, that bacteria can also be destroyed by sound vibrations.

Disinfection by biological agencies. — If the infectious elements in any given case can be deprived long enough of food, starvation must eventually ensue; and there is little doubt that in certain water supplies, and elsewhere, this condition constitutes, or may constitute, a genuine factor of disinfection.

It is also possible, of course, to have two or more of the agencies already mentioned, such as cold and dryness, light and heat, or poisons and starvation, acting together and constituting what may be called an "unfavorable environment." Contrary to earlier opinion, it is now recognized that each microörganism must be carefully adjusted to its environment if it is to survive long. Perhaps no factors are more effective in the control of infection than the unfavorable environments of infinite variety to which such organisms are often subjected. It is important to remember, however, that while the lower forms of life may suffer from high mortality in an unfavorable environment, their powers of reproduction are so great and the reproductive cycle is so short, that they are also remarkably adapted to survival. In fact, in many ways, they are adapted to survive much more successfully than man, and whether or not the latter can maintain his superiority over the innumerable small forms of life that invade and infest him, that attack his food, his clothing, and his shelter, depends entirely on the constancy and effectiveness with which he wages the eternal struggle against them, for they represent his greatest enemies.

The problem of disposal of the dead. — The question of the sanitary disposal of the dead concerns us chiefly so far as it relates to the spread of disease, and it is only this aspect of the subject which will be touched upon here. It has been noted earlier in the text that the bacterial population of the living earth is a scavenging population which disintegrates the organic matters falling upon the earth, and converts them into inorganic matters. The same thing is true of organic matters placed at a moderate depth in the crust of the earth. The subsoil is less abundantly supplied with bacteria than the loamy layers of vegetable mold at or near the surface, but it also contains a sufficient number to bring about the somewhat less rapid decomposition of organic matters. Human bodies, therefore, buried in the earth, and the

wooden boxes in which they are usually interred, are over a long period of time gradually mineralized.

The experiments of Dr. Charles Wardell Stiles, formerly of the U.S. Public Health Service, are especially interesting in this connection. Some years ago, at Wilmington, N.C., he buried human excrement at varying depths, and found that such organic matter buried at depths between three and six feet hardly underwent any disintegration or mineralization in six months time. Furthermore, the use of metal caskets and embalming fluids (which are usually powerful disinfectants, or at least strong antiseptics), simply delays the process of mineralization in the burial of the dead. If any disease germs be present in or about the dead body, these are obviously harmless so long as they remain in the earth. The only question is whether they may survive to be brought to the surface by earthworms or other agencies or be carried away in the ground water supply. This subject has been carefully investigated and there seems little reason to believe that infectious materials may readily be spread abroad from infected bodies buried in the earth. Moreover, there are good grounds for believing that owing to an unfavorable environment, the pathogenic germs, if present, will generally not survive very long; so that it is safe to conclude that from the sanitary point of view there is little to be feared from the disposal of the dead by interment.

Much has been written and claimed in regard to noxious vapors arising from graveyards and in regard to graveyards being sources of disease. These ideas, however, are not founded upon good evidence, and there is every reason to believe that whatever diseases may have appeared in the neighborhood of graveyards have had their origin elsewhere.

Interment *versus* cremation. — If this be true, then no powerful argument can be found in sanitary science for cremation as opposed to interment. Nevertheless, for the following reasons cremation seems to be the better process for the disposal of the dead: first, because it is speedy rather than tardy, and is accomplished by cleanly combustion rather than by foul decay; second, because of the smaller space required for keeping the ashes and the possibility of restricting the immense areas likely in the future to be required for cemeteries; and third, because of the removal

of all ground for debate as to the possibility of the origin of disease from graveyards.

Terminal *versus* concurrent disinfection. Fumigation. — In the early days of the modern public health movement, when the view still prevailed that disease germs could travel readily through air, or survive for long periods of time on objects in the sick room, great emphasis was placed on terminal disinfection. After a case of communicable disease had terminated, fatally or otherwise, the room was shut, all cracks and crevices to doors and windows were sealed with heavy adhesive paper, and the contents of the room were " disinfected " by fumigation. At first sulphur dioxide gas was employed, but when its limited value as a germicide was established, formaldehyde gas was substituted. Often, too, the bedding was destroyed by incineration, or removed to large steam sterilizers for disinfection. Doubtless very little if any value resulted from these practices. On the other hand great injury to property resulted, the afflicted family was put to considerable inconvenience, and the emphasis was entirely misplaced.

A much more rational point of view has since been adopted. Terminal fumigation for the ordinary communicable diseases, such as tuberculosis, diphtheria, scarlet fever, typhoid fever, and the like has been abandoned wherever progressive health measures are in force. Instead, emphasis is placed on concurrent disinfection, *i.e.*, the collection of the secretions and excretions of the patient, and the destruction of the pathogenic agents which they contain either by incineration, boiling, or the use of chemical disinfectants. Furthermore, the napkins, bed linen, towels, handkerchiefs, eating utensils, and other things used by the patient must be segregated, so that they are not used in common by other members of the household, and these articles are sterilized regularly by boiling. At the termination of the disease, the patient's linen is thoroughly laundered, the floor and woodwork are washed with soap and hot water, and everything in the room is exposed for at least a day to the germicidal effects of fresh air and sunshine. Cleanliness, personal and environmental, coupled with isolation, have been substituted for the blind and ignorant destruction of property, the burning of incense, or the liberation of other noxious vapors or gases in the control of secondary cases of disease.

There are, however, instances where fumigation is of the first importance. Such conditions arise where the disease in question

is not spread by contact or by infected food and drink, but through the agency of insects. Diseases like typhus fever (spread by the body louse, and in the United States also apparently by the rat flea) yellow fever and malaria (spread by mosquitoes), bubonic plague (spread by rats and the fleas that infest them) — these are a few examples of situations where fumigation is of great value. Ships coming from plague infested ports are often fumigated with hydrocyanic acid gas before the cargo is removed, care being taken, in the meantime, to prevent the escape of rats in the hold of the vessel, by means of mechanical devices, such as large, inverted, metal funnels, which are adjusted to the hawsers that hold the ship to its pier. Thus, by a thorough comprehension of the sources and modes of infection, needless efforts at disease control have been eliminated, effective measures have been substituted, and the personal as well as the public health has been safeguarded.

CHAPTER XVIII

MOSQUITOES AND THE PUBLIC HEALTH

Man's greatest enemies. — The progress which has been made first, in the knowledge that mosquitoes may be vehicles of disease, and second, in the control of such widespread diseases as malaria and yellow fever provides another romantic chapter in the history of sanitation and preventive medicine. In the constant adjustment between the individual and his environment man learned to protect and guard himself against the larger and visible enemies with relative facility, but the adjustment of man to his small and invisible foes came long after he had subdued the grosser aspects of his environment. These enemies could not be seen and hence their significance could be appreciated but imperfectly. They were punishments or evils that had to be endured.

The bacteria, the protozoa, the mosquitoes, flies, lice, and other forms of life that prey on man, multiply with startling rapidity under favorable conditions, and are ceaseless in their search for food. They represent the greatest challenge to man's supremacy on the earth that has yet become apparent. It was a great accomplishment to have discovered the relationship of bacteria and protozoa to the diseases of man, and the part played by mosquitoes, flies, and lice as well as other vehicles in the transmission of disease. But to have learned how to bring these diseases under control and to have accomplished that end are achievements which rank among the finest and most precious triumphs of man. Without them our average span of life would be brief, good health relatively rare, and the normal enjoyment of life well-nigh impossible. Yet it is but a scant fifty years since some of these discoveries were made and already life has become a different thing to millions of people on our globe.

The universality of malaria and yellow fever. — The emphasis which is placed on the elimination of mosquito-borne diseases like malaria and yellow fever is indicated by the support which the Rockefeller Foundation has given to this work in all parts

of the world. As recently as 1931 anti-malarial work, consisting of control programs, field studies, research, and the training of personnel, was being financed in several of our southern states, as well as in twenty-four foreign countries. These included Grenada, Jamaica, Puerto Rico, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, Salvador, Venezuela, Albania, Bulgaria, Corsica, Germany, Greece, Italy, the Netherlands, Rumania, Spain, Jugoslavia, Ceylon, India, Palestine, and the Philippine Islands. Extensive yellow fever studies and control work have been carried on or supported by the Foundation in Brazil and West Africa particularly, but also in Mexico, Central America, Ecuador, and Peru. These geographic lists attest the universality of malaria and yellow fever. The latter disease has been brought under control to a remarkable degree, for according to reports issued by the Health Section of the League of Nations, the total number of definite clinical cases of yellow fever recorded all over the world in 1931 was but 123, and of this number 18 were suspected cases. A total of 41 yellow fever deaths was also recorded during the same period, 17 from West Africa and 24 from Brazil.

Reasons for anti-mosquito activities. — There are two main reasons why anti-mosquito activities are prosecuted with great vigor. The first is because the insect is a pest, causing great annoyance to man during his wakeful hours in the mosquito season, and disturbing his peace and repose during the hours of sleep. These insects interfere with land development and utilization and in general tend to keep the economic level of their environment at a low ebb. The second and more important reason is because they are involved in the transmission of certain diseases, among which are malaria, yellow fever, dengue fever, blackwater fever, and filariasis. Of these, the control of the first three are of primary importance to the welfare of the United States, but now that yellow fever has been virtually eliminated from the civilized world, malaria is unquestionably the most important mosquito-borne disease.

Distribution of malaria. — Malaria, one of the most widespread of human diseases, occurs in almost all parts of the world except the polar regions and waterless deserts. Generally speaking, malaria is most prevalent in the tropics and subtropical belt, and diminishes gradually both to the north and south, until the

Arctic and Antarctic circles are approached. All of Africa is malarial, but the worst region is located on the west coast of that continent. Malaria is also widespread throughout Asia, the East Indies, and Australia. It is especially prevalent in India, Ceylon, and Borneo. In India alone there are probably still over 1,000,000 deaths from malaria annually. In Europe, Great Britain and Norway are practically free from malaria, but most of the other countries, especially those in southern and southeastern Europe are endemic malarial foci. Italy has been plagued with malaria for centuries. It is not unlikely that the Roman legions carried the infection to all regions which they conquered, and if the malarial mosquito was native to these areas, the disease became firmly established in this manner.

Malaria is also very prevalent in the western hemisphere, in Central America, the West Indies, Mexico, the greater part of South America, and in the southern part of the United States. Canada is not markedly infected, while Greenland is supposedly free of the disease.

In the United States the infected areas extend from the state of New York along the Atlantic seaboard to Florida, and westward to the state of Missouri and south through all the states bordering on the Gulf of Mexico. Malaria has also developed in the fertile valleys along the western coast of the United States and in the reclaimed arid regions of the southwest.

The malarial toll. — It is estimated that in the United States alone there are over 6,000,000 cases of malaria each year. While the actual toll in deaths is large, it is small in proportion to the number of cases. The indirect toll of malaria is very heavy, however, for it often paves the way for the development of other diseases because of its debilitating effects. In addition it causes enormous economic loss and greatly retards industrial and agricultural development. Wherever malaria prevails, absenteeism from industry often occurs, necessitating frequent turnovers of labor with a resulting loss of efficiency. On the other hand efforts to restrict or eradicate malaria in a community result in better health, increased industry and prosperity, better housing conditions, and generally improved environmental sanitation, all of which operate for the still further elimination of mosquitoes and the control of malaria. Dr. L. O. Howard, former Chief of the Bureau of Entomology of the U.S. Department of Agriculture,

estimates that the economic loss in the United States due to malaria is approximately $100,000,000 a year.

How progress in a malarial area may be retarded can be illustrated by numerous examples. Dr. H. R. Carter of the U.S. Public Health Service states in *Public Health Bulletin No. 104* that "a striking illustration of the disastrous effect of malaria is afforded by the history of the lower peninsula of Virginia. Constituting, as it did, the earliest English settlement in America, and containing as it does excellent farming land, it is significant that this region is still practically uninhabited. On many parts of the peninsula there is hardly a family to three square miles. Though school histories do not mention the fact it is on record that Jamestown was abandoned 'because of epidemicals.' For the south as a whole it is safe to say that typhoid fever, dysentery, pellagra, and tuberculosis, all together, are not as important as malaria." Evidence shows that the richest portion of the Mississippi delta, still but sparsely settled, has not been developed because of the unusual prevalence of malaria. As an example of its ravages in industrial communities one may cite Roanoke Rapids, Virginia. Here, prior to the inauguration of malaria control operations, the managers of the cotton mills estimated that their employees exhibited only 40 to 60 per cent of their normal efficiency during the malarial season of four months.

Still another illustration must be mentioned because of its historic significance. The Pontine Marshes near Rome have been malarial for centuries. Recently, due to the anti-malarial activities of the International Health Board of the Rockefeller Foundation, whole areas have been reclaimed and made salubrious once more. Speaking of the work done in the town of Sermoneta on the edge of the Pontine Marshes, the annual report of the Rockefeller Foundation for 1928 says that 'during the last three years the population of the town has begun to show an increase after remaining stationary or decreasing for more than six centuries."

The experiences of the British Expeditionary Force in the Near East during the World War testify to the importance of malaria as a devastating force to armies engaged in military operations in a malarial district. Thousands of soldiers were invalided back to England for treatment because of malaria contracted during the campaigns in this region. According to Dr. Lewis Hackett

of the Rockefeller Foundation, General Allenby, during his occupation of Jerusalem, controlled malaria in that city by oiling 60,000 wells used as sources of drinking water in that community. It is easy to see that success or failure in military operations may often depend not on the courage of men or the tactical skill of officers, but on such extraneous causes as malaria if the forces are engaged in a malarial district.

Classification of mosquitoes. — Mosquitoes belong to the Order Diptera of Class Insecta, a subdivision of one of the Phyla of the Arthropoda. The Diptera are divided into numerous Families among which is the Family Culicidae which includes all mosquitoes. The Culicidae in turn are divided into numerous Genera, and each Genus contains many species. Over 2,000 different species of mosquitoes, some of which are without pathologic or economic significance, have been described as occurring throughout the world. Many species may inhabit a single area, *e.g.*, over forty species have been found in New Jersey alone.

Culex pipiens. — Before discussing the relationship of mosquitoes to the transmission of disease it is desirable to describe briefly their biology and life history. This is well shown in the common pestiferous mosquito so plentiful in all parts of the United States, and which interferes so greatly with the enjoyment of outdoor life during the warmer months of the year. This insect is known as Culex pipiens. It does not transmit disease and is normally regarded simply as a pest. Together with other species and especially the salt marsh mosquito, Aëdes sollicitans, it has detracted from the pleasures of suburban and country life and recreation at ocean resorts. The extensive construction of ditches in the tidal marshes on Cape Cod, and to a more limited extent in the region just north of Boston, has in recent years made life in these areas more comfortable and pleasant. Similar operations in the tidal marshes near Newark, N.J., have opened up large areas for industrial development besides enhancing the comfort of thousands of residents in New Jersey and New York.

Culex pipiens is a fresh water mosquito. In the natural state it breeds in any stagnant water, as in swamps, quiet pools, or on the margins of slow running streams. Near habitations, any open water containers such as rain barrels, cisterns, tin cans, catch basins, roof gutters, or even flower vases may serve as breeding places. During the winter the insects hibernate in cellars, under

buildings, or in hollow trees and other dark shelters, or are possibly frozen in the ice of pools and swamps.

All mosquitoes pass through a life cycle consisting of four stages, the egg, the larval stage, the pupa, and the adult mosquito or imago. Under favorable conditions of temperature and food supply the entire life cycle of Culex pipiens may be completed in seven to ten days. The female begins to lay eggs on the surface of stagnant water early in the spring. These appear in small raft-like masses containing anywhere from 50 to 300 or possibly 400 eggs. A few days later the larva hatches out. In warm weather the larvae develop from the eggs within a day. The larval stage represents an active, feeding period which lasts about a week. The larvae molt four times during this period and are so active that they are known as "wigglers" or "wiggle-tails." They are provided with little mouth brushes which are constantly in motion and which bring to the mouth the various organic and inorganic particles that are either in solution or in fine suspension in the water. Practically everything small enough in size is ingested, the larva exhibiting no discrimination. Much of this material passes through the alimentary tract unchanged and can therefore not be classified as food. At the end of the larval period the developing mosquito passes into the pupal stage in which it is still exceedingly active, although it does not take in any food. This stage lasts a day or somewhat longer, when the pupal covering splits longitudinally and the adult winged mosquito emerges.

Flight of mosquitoes. — How far mosquitoes may fly from their breeding place is a question which has been the subject of considerable conjecture and some study. Exact information is not available. Conservative estimates, however, indicate that mosquitoes can travel under their own power a distance of at least two miles. During the hibernation period distances as great as five miles have been recorded. Salt marsh mosquitoes have been found forty miles from their breeding place, but it is not known whether they were carried over this distance in vehicles or by the aid of the wind. Recent experiments with malarial mosquitoes released in airplanes show that they can be carried hundreds and even a thousand miles or more in this way, in spite of numerous intermediate landings and exchange of passengers and baggage. It is obvious, therefore, that although mosquitoes do not travel very far from their breeding places under their own power they

may travel great distances in the speedy conveyances of man. With the increasing use of airplanes for transportation purposes the introduction of infected mosquitoes into regions hitherto free of infection is entirely possible, thus creating a new public health problem of considerable importance.

Since the methods of mosquito control employed are applicable to a greater or less degree for all species, no special consideration will be given at this point to the elimination of Culex pipiens, the household mosquito, or to Aëdes sollicitans, the salt marsh mosquito, but the whole subject will be discussed later.

Malaria. — Malaria is a group name for closely related infections due to protozoan parasites that live in the blood of man and that are transmitted by many species of the anopheles mosquito. There are at least three separate malarial parasites that affect man. One is Plasmodium malariae discovered by Laveran in 1880 which gives rise to Quartan Fever. A second is Plasmodium vivax discovered by Grassi and Feletti in 1890 which causes Tertian Fever, sometimes also known as Benign Tertian Fever; and the third is the Plasmodium falciparum discovered by Blanchard in 1905 which gives rise to Estivo-Autumnal Fever which is also known as Malignant Tertian Fever. These parasites are closely related hemosporidia or blood parasites capable of producing diseases with well-defined clinical differences. They are all transmitted to man through the bite of the anopheles mosquito, so that from the standpoint of control they may be regarded as one infection. Quartan fever is comparatively mild and rare; tertian fever is very common, while estivo-autumnal fever is quite prevalent, especially in the tropics, and is the most malignant and pernicious form of malaria. Mixed infections also occur. The type of infection can be determined by identifying the parasite microscopically in the examination of blood smears made from patients, and also by observing the clinical symptoms of the disease.

Epidemiological aspects. — The widespread prevalence of malaria throughout the world and its public health, economic, commercial, and military significance have already been emphasized. The French attempt to build the Panama Canal failed, not because of inferior engineering ability or lack of financial support, but because of the devastating effects of malaria and yellow fever. The Americans succeeded because Colonel Gorgas, who was in charge of the sanitation of the Isthmus of Panama, was first able

to organize methods for the control of the mosquitoes responsible for these two diseases.

So far as known no animal other than man has been shown to be a reservoir of human malarial infection. Certain of the lower animals suffer also from malaria, but the parasites that affect them are of different species from those that produce malaria in man. Similarly, although there are numerous genera of mosquitoes in the world, there is only one genus that is associated with the transmission of malaria, namely, the genus Anopheles. At least 25 different species of anopheles mosquitoes are known to transmit malaria in different parts of the world, and each has its own special range or region to which it is indigenous. Often more than one species is found in a given zone. It is therefore important in the control of malaria in any given part of the world, to determine which type of mosquito is responsible for the transmission of the disease, to become familiar with the life habits of these insects, and to organize a campaign of control based on this information. It is impossible to transfer the preventive technique of one country to another and expect it to function successfully.

In the United States, the anopheles mosquitoes that play a part in the transmission of malaria are A. quadrimaculatus, A. maculipennis, A. crucians, A. pseudopunctipennis, A. punctipennis, and A. albimanus. Of these six species, Anopheles quadrimaculatus is the most widely distributed and is therefore the most important vehicle of malaria in this country. The Anopheles maculipennis, an important vector of malaria in California, is the most significant conveyor of malaria in Europe and certain parts of Asia. Anopheles punctipennis is also quite widely distributed throughout the United States, and although it is capable of transmitting the tertian and estivo-autumnal types of malaria it is regarded as unimportant. Anopheles pseudopunctipennis transmits malaria in northern California, and is the most important insect in relation to malaria transmission in northern Argentina. The Anopheles albimanus is found in the United States only in the extreme southern portion, but it is quite common in the West Indies, Central America, and Panama. In these regions this species and Anopheles tarsimaculatus are the leading vectors of malaria.

In other parts of the world still other species of anopheles mosquitoes are chiefly associated with the transmission of malaria. In India, it is Anopheles sinensis, in Africa, Anopheles costalis, in

Spain, Anopheles claviger, and in the Philippine Islands, Anopheles minimus. There are some species of anopheles which have never been associated with malaria. This does not mean, however, that they are unable to transmit the disease, and in any control work they must always be regarded with suspicion.

There is no natural immunity in malaria. Everyone is susceptible, children more so than adults, probably because their skin is more readily punctured by the proboscis or biting apparatus of the mosquito, and they are less able to protect themselves. Repeated attacks of malaria do, however, confer a certain amount of immunity. For this reason newcomers in a malarial district always suffer more from malaria than the natives. There is no variation in infectivity according to sex and all races of man are susceptible.

In regions where malaria is constantly present, at least 20 to 40 per cent of the population will show the presence of malarial parasites in the blood. Sometimes the proportion infected may reach the high total of 90 per cent. Since many cases of malaria are only ambulatory they become carriers of the infection and hence are a menace to the uninfected members of their community. To this group must be added the large number of individuals who become carriers of malaria through the incomplete treatment of the disease. Sometimes the parasite may remain latent for long periods in the spleen or other organs of the body and produce symptoms of malaria only when the vital resistance of the individual is lowered by exposure, lack of proper nutrition, overwork, or other debilitating factors. It is estimated that in most malarial regions about 20 per cent of the apparently healthy natives harbor the parasite of malaria, and that of this number, 50 per cent have the parasite in the circulating blood. In regions that are badly infected as many as 60 to 70 per cent of the apparently healthy natives may be carriers. The recognition of carriers is determined by the microscopic examination of blood smears made from suspected individuals, but the malarial index of a community is determined by palpation of the spleen and by ascertaining in this way the proportion showing the enlargement which is characteristic in a high proportion of infected cases. In determining the proportion of a population showing enlargement of the spleen it is customary to examine children under 15 because they give more constant results and also because of their ready availability through the schools.

The existence of malaria in a community is thus always dependent on two factors, the mosquito capable of transmitting the parasite and humans harboring the parasite in the blood. It is conceivable that malaria may be introduced into a community free of the disease simply by the introduction of infected mosquitoes, but this method is rare in comparison with the other. It is therefore of interest to inquire into the proportion of anopheles mosquitoes in malarial districts that harbor the malarial parasite. In general, less than 5 per cent of the mosquitoes examined have been found to be infected. In Bombay, however, the proportion found infected was approximately 25 per cent and in certain parts of Africa, as many as 50 per cent of the malarial mosquitoes were infected.

Malarial mosquitoes do not feed on human blood alone. In fact mosquitoes in general live on plant juices. Furthermore, it is only the female that draws blood. The thirst for blood is believed to be somehow associated with the production and fertility of the eggs. The proboscis of the male mosquito is unable to pierce the skin of man or other animals, so that only the female is able to transmit the infection. In 1923 numerous Anopheles quadrimaculatus were caught at Mound, La., and examined to identify the origin of the blood found in the female mosquitoes. The results showed that 35.7 per cent fed on cows' blood, 32.6 per cent on horse blood, 16.1 per cent on pigs' blood, 8.3 per cent on dogs' blood, 3.0 per cent on chicken and cat blood, and only 4.3 per cent on human blood. It is obvious, therefore, that malarial mosquitoes use other bloods than human, and it would seem that the blood of animals more exposed and less capable of self-protection is obtained with greater frequency than the blood of man. This explains why certain areas are comparatively free of malaria, even though anopheles mosquitoes are very prevalent, and malaria is found abundantly in surrounding communities.

Proof that malaria is transmitted by mosquitoes. — Prior to the adoption of the theory that mosquitoes are responsible for the transmission of malaria to man, malaria was supposed to be due to bad air, fogs, or "miasms" arising from swamps, particularly at night. In fact, the name malaria itself is composed of two separate words, mal and aria, meaning bad air. Patrick Manson, a British physician, was among the first to associate malaria with the anopheles mosquito. It was he who stimulated Sir Ronald Ross, a Major in the British Medical Service in India, to work on the life

cycle of the malarial parasite in the anopheles mosquito. Laveran, a French physician, working in Algeria, had found an amoeboid organism in the blood of malarial patients as early as 1880, and had definitely established the relationship of this parasite to malaria in man. He also traced the various stages of the development of the malarial parasite in man, but it remained for Sir Ronald Ross to complete our knowledge of the life cycle of the malarial parasite by showing that the second phase of this cycle is passed in the female anopheles mosquito. This he did in August, 1897, after two and one-half years of constant research.

Although the life cycle of the malarial parasite had thus been placed on a firm scientific foundation, there was still needed the carefully controlled demonstration that malaria is transmitted by the bite of the infected anopheles mosquito *and in no other way.* This proof was forthcoming in 1900 through the efforts of Doctors Sambon and Low, two well-known British physicians. The Roman Campagna had been famous as a hotbed of malaria for centuries and life in this region was destined to result in malaria without fail. Dr. Sambon and Dr. Low proposed to live on the Campagna during a period of three months in the peak of the malarial season and to demonstrate that by exercising due precautions against attack by mosquitoes they could avoid malarial infection. This they proceeded to do, living in a mosquito-proof hut and protecting themselves thoroughly against mosquito bites. During the daytime they went about the neighborhood freely in all kinds of weather. They drank water from the swampy streams, slept freely exposed to marsh air, and did everything that was commonly believed to produce malaria. At sundown, however, they retired to their mosquito-proof hut where they remained until the following morning. In spite of the dangers on all sides, for all of their neighbors suffered from malaria, and with no attempt to employ quinin prophylaxis, they came through this period entirely free from malaria.

But this was only negative or presumptive proof that the anopheles mosquito was associated with the transmission of malaria, for they had merely protected themselves from being bitten by mosquitoes. It was now necessary to obtain positive proof of the rôle of the anopheles mosquito in the transmission of malaria. This, too, was forthcoming, and in a rather dramatic way. Mosquitoes that had fed on malarial patients living in the Roman

Campagna were captured and shipped alive to England. There they were released in a sealed room, and allowed to bite two volunteers, one of whom was the son of Dr. Patrick Manson. Neither of these individuals had ever been exposed to malaria in any way. In time, the two subjects both developed malaria and the parasites of the disease were found in the blood of each. The evidence was conclusive that malaria is transmitted to man through the bite of an infected anopheles mosquito.

On December 12, 1902, Ronald Ross was awarded the Nobel prize in medicine for his epoch-making work on the life cycle of the malarial parasite in the anopheles mosquito. He had shown experimentally, using female mosquitoes that had bitten malarial patients, that the ingested parasite first penetrates the stomach wall of the mosquito where sexual development takes place. The cells later gain access to the lymph system, and after a suitable period, make their way into the salivary gland where certain further changes occur, after which they pass with the salivary fluid through the proboscis into another human being during the process of biting. In the lecture which Ronald Ross gave on this occasion he quotes his own amazement over the things his microscope disclosed. He said: "The exact route of infection of this great disease which annually slays its millions of human beings and keeps whole continents in darkness, was revealed. These minute spores enter the salivary gland of the mosquito, and pass with its poisonous saliva directly into the blood of men. Never in our dreams had we imagined so wonderful a tale as this."

Clinical symptoms of malaria. — After an individual is bitten by an infected anopheles mosquito a certain amount of time must elapse before the characteristic symptoms of the disease make their appearance. This is known as the incubation period. In quartan fever the incubation period varies from 11 to 18 days; in benign tertian fever it is from 7 to 25 days; and in estivo-autumnal fever it is from 9 to 10 days.

The disease is characterized by chills and fever. This is true for the various forms of malaria, although in the estivo-autumnal type the non-febrile interval is not at all certain. The febrile period may be divided roughly into three stages, (1) the stage of chill; (2) the hot stage; and (3) the sweating stage. At the beginning of the attack the patient feels cold. This sensation increases until actual shivering sets in. The chill lasts from 15 to 30 minutes. In

the meantime the temperature of the patient rises steadily until a maximum is reached. After the chill the patient feels warmer and more comfortable, and by degrees the sensation of warmth increases until the patient becomes burning hot. The hot stage usually lasts from 3 to 4 hours. Towards the end of this stage the forehead becomes moist and presently beads of perspiration begin to appear. Perspiration now becomes general and profuse and the patient experiences great relief. As the sweating increases the temperature of the body falls rapidly, and as it approaches normal the patient may fall into a deep sleep from which he awakes feeling refreshed and improved. The patient feels weak but may be able to perform his ordinary tasks in a semi-efficient manner. The total duration of the attack described above may last from 8 to 10 hours. After a suitable interval elapses, the time depending on the type of infection, another attack of chills and fever similar to the first is experienced. These paroxysms coincide with the development of the malarial parasite in some of the red blood cells of the body and their subsequent destruction.

Life cycle of the malarial parasite. — As mentioned above, the life cycle of the malarial parasite is divided into two stages, one of which is passed in the blood stream of man and the other in the body of the female anopheles mosquito. The stage in man is asexual while the stage in the mosquito is sexual. Man is therefore the intermediate host for the malarial parasite while the female anopheles mosquito is the definitive host. Both stages must be completed before malaria can be transmitted by natural methods. The asexual cycle in man is completed in 24 to 48 hours for Plasmodium falciparum, 48 hours for Plasmodium vivax, and 72 hours for Plasmodium malariae. The sexual cycle in the anopheles mosquito is completed in about 10 days for Plasmodium falciparum, about 14 days for Plasmodium vivax, and about 21 days for Plasmodium malariae.

The invading parasite in the body of man is known as a sporozoite. This organism is introduced into the circulatory system where it attaches itself to or penetrates one of the red blood corpuscles. It is less than one-thousandth of a millimeter in diameter. Soon it forms into an active amoeboid body, somewhat greater in size, but still smaller than the red blood cell. In this form it is known as a schizont. The schizont matures at the expense of the red blood corpuscle, eventually occupying most of it. By this time

the amoeboid movements are not so active. The mature schizont finally divides into a number of separate cells, each with a separate nucleus. These corpuscles are given off into the blood plasma and are known as merozoites. The number of merozoites formed depends on the type of the malarial parasite. With Plasmodium malariae, 6 to 10 merozoites develop from each schizont, with an average of 8; with Plasmodium vivax, the number of merozoites per schizont varies from 12 to 24 and averages 16; while with the Plasmodium falciparum, the number of merozoites per schizont varies between 10 and 32, and they are especially small in size. Each merozoite is potentially able to invade a separate red blood corpuscle and to repeat the asexual cycle. The production of these merozoites in sufficient concentration coincides with the malarial paroxysm.

A certain number of the merozoites do not enter fresh red blood corpuscles but develop instead into the two sexual forms of the malarial parasite, the macrogametocyte or female organism, and the microgametocyte or male organism. When mature, each organism is larger than its corresponding mature schizont, the female organism usually being larger than the male and containing more food material and a smaller nucleus. In estivo-autumnal fever these organisms are crescent-shaped, but in the other types of malaria they are spherical. Later, when the blood in which they are present is withdrawn, and is brought momentarily in contact with the air, the microgametocytes give rise to from 4 to 8 flagellated male elements known as microgametes, and the macrogametocyte gives rise to a female element known as a macrogamete. The microgametes are then able to fertilize the macrogametes. This portion of the life cycle of the malarial parasite takes place in the stomach of the malarial mosquito and is part of the sexual cycle.

After the anopheles mosquito has removed from the malarial patient or carrier blood containing micro- and macrogametocytes, the male and female sex elements are formed and fertilization takes place. The fertilized macrogamete is known as the oökinete or zygote. This organism, which is motile, bores through the epithelial lining of the stomach of the mosquito and embeds itself in the muscle tissue. Here it forms a cyst and in that stage the parasite is known as the oocyst. Here it grows and matures, eventually forming sporozoites which fill the cyst. After about 10 to 12 days,

under tropical conditions, and longer at lower temperatures, the cyst ruptures and the sporozoites are set free in the stomach of the mosquito. From here they are carried by the lymph to all parts of the body and eventually reach the salivary gland in the thoracic cavity. The mosquito is now infective. Since the salivary gland is connected directly with the proboscis, the organ for boring and sucking, the sporozoites are introduced directly into the blood stream of the individual bitten and malarial infection in man is begun. The cycle proceeds once more in the manner already described.

Duration of mosquito infectivity. — The duration of infectivity in the mosquito depends on its longevity. This in turn is dependent on various environmental factors, among which a favorable temperature is important. In order for malaria to prevail to any extent in a given region it is necessary not only to have human cases and carriers of the disease, and a sufficient number of uninfected individuals, but it is also essential to have anopheles mosquitoes, suitable breeding places for these insects, and an average daily temperature of at least 60° F. extending over several weeks. In the tropics and subtropics these conditions are readily fulfilled. In the higher temperate regions suitable temperature conditions do not long persist.

According to Ronald Ross the female anopheles mosquito can live in nature for at least one month. If she is infected she can transmit malaria throughout this period whenever she bites a susceptible individual and introduces the parasite into his circulatory system. In the laboratory anopheles mosquitoes have been kept alive for five months. It is also well known that some mosquitoes hibernate throughout the winter. It is obvious, therefore, that mosquitoes can survive for reasonably long periods. The arrival of cold weather, however, decimates their ranks and makes further control work temporarily unnecessary. Those mosquitoes that enter the home, barn, or stable at such periods should be ferreted out and destroyed.

Characteristics and breeding habits of anopheles mosquitoes. — The control of malaria depends on a thorough knowledge of the physical characteristics and life habits of the mosquito. Without anopheles mosquitoes there cannot be any malaria, and while their complete extermination is difficult of achievement, their numbers can be reduced sufficiently by a well-planned and care-

fully executed anti-mosquito campaign based on a knowledge of the life cycle and habits of the malarial mosquito. In fact, it is essential to determine first which species of anopheles mosquito is involved in the transmission of malaria in a given locality, to know its habits and life cycle, and to organize a campaign of extermination against this particular insect. Evidence was presented earlier in this chapter to show that different anopheles mosquitoes are involved in the transmission of malaria in various parts of the world.

The anopheles mosquitoes are brownish in color and rather large. There are definite physical and biological characteristics that distinguish them from the genus Culex, our common annoying types, and the Aëdes which includes the variety responsible for the transmission of yellow fever and dengue fever. In the anopheles mosquito the palpi in the male and female are equal in length with the proboscis, or may be slightly longer. In the culex and aedes varieties the palpi in the female are shorter than the proboscis and longer in the male. An interesting difference is also observed when both groups of insects rest on a vertical wall. In the case of the anopheles the proboscis is in a straight line with the central axis of the body, and the mosquito stands at an angle of about 45° to the vertical. With the culex and aëdes varieties the proboscis is not in direct line with the body axis. In fact the body is held either parallel to the wall or the tip of the abdomen is inclined toward it. Furthermore, the wings of anopheles are dusky and spotted whereas the wings of culex and aëdes are not spotted.

There are also certain distinct differences in the aquatic forms of these mosquitoes. The eggs of the anopheles mosquito are laid singly or in small numbers on the surface of the water. In the case of the culex mosquito, the eggs are laid in clumps or masses to form a raft. The larvae also differ considerably. The larvae of the anopheles mosquito do not have any respiratory siphon. When at rest they float in a horizontal position below the surface of the water. The culex, however, has a respiratory siphon which is in contact with the surface layer of water, and when at rest floats suspended in the water in an oblique or vertical position and almost directly in line with the respiratory siphon.

The Anopheles quadrimaculatus which is the most important malarial mosquito in the United States breeds especially in ponds,

rice fields, marshes, and pools with abundant vegetation. It is not a domestic or house-seeking mosquito in its breeding habits and in this respect is also quite different from Culex pipiens and Aëdes egypti. Anopheles quadrimaculatus, like other anopheles mosquitoes, bites only at night. In a malarial district it is therefore important to avoid exposure to mosquitoes after sundown. The adult mosquito lays its eggs on the surface of the water, and after about a day the eggs hatch into larvae. The larvae are very small, active, and almost in constant search of food. Although they do not have any obvious breathing tube, such as the culex and aëdes mosquitoes possess, they are also air breathers, and come to the surface frequently for air. This fact is utilized in one of the control measures against the mosquito, since the application of oil to the surface of the water containing larvae results in the clogging of the breathing apparatus and the subsequent suffocation of the organism.

In the larval form the head is smaller than the thorax. Rotary brushes are observed near the mouth which bring to it the various particles in the immediate environment that may be used for food. There is no discrimination between particles that can be used as food and those that cannot. Hence when Paris green is used as a larvicide, the particles are taken into the body by way of the mouth and death results by poisoning. The larval stage lasts for at least five days, depending on the temperature, after which the pupa is formed. The pupa is comma-shaped and apparently all head and tail. It does not possess a mouth and hence does not feed. The pupa floats quietly at or near the surface of the water unless it is disturbed, when it will seek protection in the lower layers. The pupal stage lasts from one to two days after which it splits down the back and the adult winged mosquito emerges on the surface of the water. Under the most favorable conditions of temperature the period from egg to adult mosquito in this aquatic stage of its existence lasts at least seven days. When the temperature is lower the duration of the cycle is prolonged.

The anopheles mosquito shows an interesting and very definite relation to temperature, which influences not only the duration of the aquatic stage of mosquito development, but likewise affects the mating activities and the deposition of eggs. Temperature also determines their habitat at different seasons of the year, the stage in which the insect hibernates during the winter, and also

their blood sucking propensities. Since the insects are not warm blooded organisms like mammals, their own temperature is essentially that of their environment. Hence in their behavior and life processes, mosquitoes respond to the daily and weekly variations in atmospheric temperature, and accordingly it is easy to understand why malaria is especially prevalent in the tropics.

Types of malaria. — Mention has been made already of three types of malaria, tertian fever, quartan fever, and estivo-autumnal fever, each of which is due to a separate parasite. In tertian fever the parasite develops asexually in man in 48 hours, and the liberation of spores coincides with the occurrence of fever. After an interval of one day, during which the fever subsides, the cycle is repeated again. In quartan fever, the asexual cycle is completed every 72 hours, so that there are 2 days during which the fever subsides. Sporulation occurs every fourth day, and since sporulation coincides with the development of fever, hence the name quartan fever. In estivo-autumnal fever sporulation also occurs every 48 hours, but the subsidence of fever may be only partial, and a more or less continued fever may obtain. When fever occurs every day the disease is known as Quotidian Fever. This is probably due to several infections with sporozoites which do not mature simultaneously, but mature at different times. Where only one infection has occurred, the parasites are all in the same stage of development, and sporulation occurs only at one and the same time. It is possible to have mixed infections where more than one type of malarial parasite is found in the blood, and it is also possible to have multiple infections of the same parasite. In quartan fever, for example, there may be simple, double, and triple quartan fever, depending on the interval between the various introductions of the parasite in this form of malaria.

Malaria control. Personal methods. — Having traced the development of our knowledge concerning malaria as a disease and its mode of transmission, it is now of interest and importance to see how this information is applied to control this great scourge of mankind. The control of malaria is accomplished most effectively only when measures directed against the mosquito itself and against the infection already present in patient and carrier are simultaneously applied. There cannot be any malaria without anopheles mosquitoes, nor can there be any malaria without human cases or carriers. Obviously, it is impossible to eliminate

the human vectors of malaria, but there is no opposition to the extermination of the mosquito. Accordingly, every anti-malarial campaign must revolve around the program of anopheles extermination, due consideration being given to the species involved and its life habits and idiosyncracies.

There are, however, certain personal measures which can be employed which aid in the prevention of malaria as well as its treatment and these must not be ignored. Of first consideration are those measures which prevent the mosquito from gaining access to dwellings. Here screens play an important part. Each window and door should be screened effectively, and all porches or verandas should likewise be thoroughly screened. All screen doors should fit tightly, in order to prevent mosquitoes from entering the house. Chimney drafts should be kept closed or screened during the malarial season. Folding screens are of little value and should not be employed. To insure durability, screens should preferably be made of copper, monel metal, or galvanized iron, of not less than 18-mesh material and preferably 20 to 24-mesh. It is also important for screens to be kept in good repair since the occurrence even of small breaks or openings may make it possible for the anopheles mosquito to gain admittance to the house.

In locating a residence in a district known to be malarial, high ground should be selected, if possible, and the house should not be located near swamps, streams, or other mosquito breeding places. Preferably, too, the house should face the trade winds. Any individual residing in a malarial district should be especially mindful about exposing himself at night. In heavily infected regions head nets and gloves should be worn. Mosquito repellants should also be employed. Care should be taken to remove by brushing any mosquitoes that adhere to the clothing before the individual enters the house.

People living in badly infected malarial regions should also form the habit of sleeping under mosquito netting in spite of other precautions which may have been taken. The netting should be free of holes, contain from 20 to 24 mesh to the inch, and should be firmly tucked in under the mattress so that it will not come loose. It must also be supported above the body in such a way that an adequately protected cell is created and be sufficiently removed from the sleeping form so as to make it impossible for

the proboscis of the mosquito to reach or pierce the skin. Eliminating mosquitoes in the house by "swatting" all that are visible every morning is another exceedingly worthwhile procedure. Usually they congregate on the inside of the screen during the early morning hours, and can be readily eliminated by a few minutes attention. Those that are visible at night, usually on the ceiling, before the lights are extinguished should also be destroyed. They may be caught in tin cans containing chloroform or kerosene.

To some extent mosquito repellants may also be employed but too much reliance should not be placed on their efficacy. The repellants are applied either to the skin, clothing, or bedding. Volatile or odorous substances such as oil of citronella, oil of eucalyptus, oil of pennyroyal, petroleum, camphor, sulphur, and naphthalene are employed. Often combinations of them are concocted either in liquid or jelly form. They evaporate or volatilize in a few hours at best and must be renewed. For the destruction of insects in the house, fumigation by burning sulphur or by releasing formaldehyde gas may be employed. In special cases hydrocyanic acid gas may be used, but as this gas is very poisonous, unusual precautions must be exercised. Pyrethrum powder may also be employed by burning, but the mosquitoes are only stupefied by this treatment, and must be collected and destroyed. Where fumigation is used, all doors and windows should be shut and all cracks and crevices should be carefully sealed before releasing the gas.

Personal prophylaxis with quinin. — Quinin prophylaxis to prevent the development of malaria in an uninfected individual has been employed extensively, but there are some who believe that it is not entirely effective for this purpose. This may be due to the difficulty normally experienced in administering suitable doses of quinin over an adequate period of time to thoroughly protect the exposed individual. Theoretically, however, personal prophylaxis properly applied and continued should prove effective in the prevention of malaria.

The administration of quinin to a person free of malaria simply assures him of the presence of an effective antidote in his blood should he become infected with malarial parasites. It does not give him any natural immunity to the disease. In fact, it does not prevent infection. It merely prevents the development of

malaria by keeping the number of parasites in the blood below the amount required to produce an attack. It does not prevent such individuals from becoming carriers, but it does keep down malaria morbidity.

In order to be effective it must be administered in sufficient doses throughout the entire malarial season. Numerous methods of administration have been tried. The two principal methods employed are those recommended by Koch and Celli. Koch's method consists in using large doses with a long interval between. He employed 15 grains of quinin sulphate for each dose on two successive days, repeating the treatment every 8 to 10 days over a period of three months. Celli's method consists in using smaller doses at frequent intervals. He recommended the use of 6 grains of quinin sulphate every day throughout the malarial season.

Quinin prophylaxis should not be employed as a substitute for anti-mosquito work or for the personal measures recommended above. At best it is only a palliative or additional procedure, but where an individual must be out at night in a malarial district, or where he is camping and is otherwise unable to protect himself effectively against mosquitoes, it is a valuable adjunct in combating the disease. It is cheap in cost, prompt in its effect, and practical under the conditions recommended.

Anti-mosquito measures. — The struggle against the mosquito may be directed against the adult form itself, or against the various developmental stages of the insect. The former is only palliative at best, while the latter, if conducted effectively, leads to a rapid reduction in the mosquito population. It is the most direct mode of attack and is commonly employed wherever extensive operations against mosquitoes are undertaken.

Swatting and fumigation as anti-mosquito measures in the home have already been discussed. Another method, trapping, is ineffective due very largely to the absence of suitable bait. A device recently introduced by the U.S. Public Health Service may have greater value. It consists of a hollow metal tube, illuminated internally, and equipped with a small suction fan. Near one end of the tube is an opening leading to a jar of potassium cyanide through a suitable connection. When used at night, the light attracts the mosquito, the suction fan pulls it into the tube, and the insect is compelled to make its way into the jar containing potassium cyanide where it is killed by poisoning.

Mosquitoes, like all forms of living matter, have their natural enemies. While they are of assistance in the destruction of the winged insect, the rôle they play is not very significant. Among the natural enemies of the mosquitoes are the lizard, spider, dragon fly, nighthawk, bat, swallow, and certain other birds.

Measures directed against the aquatic stages of the mosquito. — As the extermination of adult mosquitoes is well nigh impossible of achievement, the emphasis should be directed toward their diminution by waging a campaign against the aquatic stages of the insect. This consists first in the elimination, as far as possible, of all actual and potential breeding places. If the mosquito cannot reproduce it will soon become extinct. A second feature of the campaign consists in the utilization of all effective methods for the destruction of larvae and pupae that develop in bodies of water and which cannot be drained or eliminated in any other way.

Elimination of breeding places. — The elimination of domestic mosquitoes like Culex pipiens and Aëdes egypti can be largely accomplished by removing all the mosquito breeding places around the house. This consists of the disposal of tin cans, bottles, urns, or other water holding containers. Rain water barrels should be screened effectively and cisterns should be made mosquito-proof. The accumulation of water in roof gutters, or in ground depressions near the house should also be avoided. Catch basins should be oiled regularly during the mosquito breeding season and pools or small ponds which cannot be drained or filled in should be treated with larvicides or stocked with larvivorous fish. Culverts, drains, and open storm sewers should be inspected regularly throughout the mosquito breeding season and should be kept free of depressions where any water may accumulate, as the malarial mosquito can develop in water having a depth of only one-quarter of an inch. The bottom should preferably be made of concrete and the sides should be reasonably smooth and free of vegetation. Many of these anti-mosquito measures apply to the malarial mosquito as well as the domestic varieties.

Since malarial mosquitoes breed primarily in swamps, open ponds, sluggish streams, rice fields, etc., the measures directed against them are larger in scope and often involve engineering projects of some magnitude. They consist primarily of filling, draining, ponding, and the training of streams. Where filling can

be employed it represents an effective and permanent means of eliminating mosquitoes. Cinders, ashes, sand, and soil may be used. Where the marsh land is adjacent to a river, lake, or the sea, filling may be accomplished by pumping silt or sand into the area under treatment. Rubbish may also be used for filling in marsh land, but garbage should not be so employed. Where rubbish is used, care must be taken to fill the cans or to cover completely with cinders or soil, all broken crockery, etc., in order to prevent them from serving as mosquito breeding places.

Where filling cannot be employed satisfactory and durable results can be obtained by drainage. Marsh land can be drained by ditches of sufficient pitch, depth, and size (usually 10 inches wide and 24 inches deep) to drain the water from the land and to prevent stagnation. In draining tidal marshes the ditches are connected directly or indirectly with the sea, thus securing daily tidal flow. Such ditches are usually made with straight sides, and should be kept clear of vegetation. This necessitates frequent inspections and proper maintenance. Ditching of this character can be accomplished by the use of special machinery.

In some cases drainage is accomplished effectively through the use of subsurface drains. Sometimes vertical drainage is employed. Where subsurface drainage is used circular tile pipes are laid underground. These serve to carry off the ground water and thus to remove the surface accumulations of water. They are also effective in removing surface water or ground water in ground depressions that would ordinarily become stagnant or quiescent accumulations. Sometimes, as in swamps and marshes, vertical drainage is employed. This consists of boring holes or wells through the silt or clay that holds the water, and extending these excavations until permeable or fissured rock is reached. The bottom of the well is protected with broken stone and a pipe is sunk extending from the pit to the bottom of the marsh. The opening to the pipe is protected by suitable strainers. The surface water finds its way into the wells and becomes part of the ground water supply.

There are instances where swamps cannot be treated effectively or economically by drainage. In such instances ponding may be employed. This does not eliminate mosquitoes entirely, but it is effective in diminishing their numbers. The pond should be as deep as possible as the mosquitoes prefer not to breed in

deep water. The pond should be cleared of vegetation and other débris and the sides should likewise be kept free. Such ponds can also be treated with larvicides or stocked with larvivorous fish.

Another method of combating mosquitoes is by training streams in which they are propagating. This consists of grading the bed and straightening the course of the stream in order to provide a greater velocity of flow and to prevent the formation of quiet pools. The stream should also be cleared of vegetation and floating débris. The banks of the stream should be reasonably straight and as free as possible from vegetation and overhanging trees.

Measures directed against mosquito larvae. — These measures consist mainly of the use of larvicides and larvivorous fish. Larvicides have been employed extensively, and if employed intelligently and conscientiously, represent a cheap and effective means of mosquito control. When applied they must cover the whole surface of the water, and they must be renewed with sufficient frequency to prevent the development of new larvae. Special attention must be given to those portions of a stream, pond, swamp, or other water bearing instrument where débris, vegetation, projecting stones, or other obstructions make the uniform application of the larvicide difficult.

Among the larvicides used are soluble poisons such as niter-cake, creolin, and other creosote and carbolic compounds. They are effective only at higher concentrations and are therefore very expensive when large volumes of water are under treatment. They also render water unfit for animal use and they are of very little practical value in running water.

On the other hand oiling is used extensively and has many advantages: (1) oil is easily obtainable; (2) it can be applied without elaborate apparatus and spreads rapidly over the surface; (3) it kills the ova, larvae, and pupae of all mosquitoes; and (4) it is easy to see whether it has been properly applied. It has certain disadvantages, however, which, although not generally important, should be appreciated. It renders water unfit for drinking purposes and it may kill fish or render them unfit for human consumption. During rainy weather the value of oiling is greatly diminished, and it is necessary to repeat the treatment frequently, thus increasing the cost. This is also true of other chemical larvicides. Where oiling is employed careful supervision is required and the oil must be applied every 7 to 10 days. An

oil film is also easily broken up by strong wind action, thus lessening its efficacy. Finally, vegetation and other floating débris, must be removed before the oil is applied if its use is to be effective; otherwise special precautions are observed.

Petroleum oil in some form is ordinarily employed. A light fuel oil, or a heavier oil cut with enough kerosene, can be used to great advantage. Sometimes castor oil, cocoanut oil, or a vegetable oil is added to augment its spreading properties. A mixture found to be effective consisted of 1 part of crude oil, 4 parts of kerosene, and 0.1 to 0.2 per cent of castor oil. Strained crank case oil containing 25 per cent cresylic acid and adjusted to a specific gravity of 32 or 34 Beaume by adding light petroleum distillates has also been employed successfully in the United States. In Holland liquid paraffin has been used and many advantages are claimed for it over the ordinary petroleum oils. The amount of oil employed varies with many factors, but in general a half ounce of oil per square yard of water surface, or 15 gallons per acre, will be required.

Numerous methods are in use for applying oil, depending on the area to be covered and the prevailing conditions. Oil is applied by means of knapsack sprayers, ordinary watering pots, drip tanks, barrel-pumps, and sawdust or cotton waste soaked in oil for 24 hours.

The effectiveness of oil as a larvicide is due to a variety of reasons. Since the larvae are air breathers the application of a film of oil to the surface of the water in which they live shuts off the air supply and brings about their suffocation. Furthermore, as they bring their breathing apparatus to the surface for air, the small opening becomes clogged with a droplet of oil, breathing is frustrated and suffocation also results in this way. The application of oil to the surface of water also lowers its surface tension, making it difficult for the larvae to remain at the surface. This results eventually in drowning. The application of oil also interferes with algal development which in turn deprives the larvae of one of their important sources of food. Finally, the oil itself has a toxic effect on the larvae and a certain degree of destruction occurs in this way.

Paris green. — This is a larvicide of great value and was first introduced in 1921. It is effective against anopheles larvae but not against the larvae of the culex and aëdes varieties. This is

because anopheles larvae are surface feeders while the others are not. It is not effective against anopheles eggs and pupae since the pupal forms do not feed. Since 1921 it has been used extensively in many parts of the world, especially where vegetation is thick and where the use of other larvicides would be ineffective or less successful.

Paris green is copper aceto-arsenite. In the United States, the law requires it to contain at least 50 per cent arsenious oxide. This is exceedingly important as compounds sold under the same name which do not contain as much arsenious oxide are either ineffective or exhibit greatly diminished toxicity. Paris green should be used as a fine powder capable of passing through screens or cloth having 200 to 300 mesh to the inch. It is mixed with other substances such as ashes, road dust, slaked lime, powdered soapstone, powdered charcoal, cork dust, cement dust, powdered clay, sulphur, chalk dust, or china dust. It is usually mixed with its diluent in the proportion of 1 part to 50 or 100 parts. It is applied either by hand or by means of a blower, utilizing the wind to spread it as much as possible. In some instances it has been distributed with the aid of boats and in regions where the use of boats is difficult or impossible, airplanes have been employed.

Its effect is to destroy the anopheles larvae by poisoning. Since the larvae are surface feeders, it is important that the surface tension of the water should be great enough to support the particles of Paris green. It is also important that the Paris green should be insoluble in water. The frequency of application should be such that the development of pupal forms will be prevented. In general, this means that Paris green must be applied once in every seven days.

The advantages of Paris green are its cheapness, its high toxicity, its portability, the ease with which it is distributed by the wind, its effectiveness even in the presence of dense vegetation, the ease and rapidity with which it can be applied, and the fact that it does not render water supplies unfit for domestic or animal use in the amounts employed. It also exhibits no ill effects on fish life or on the cultivation of such crops as rice.

The use of surface feeding fish. — In the United States, surface feeding fish, particularly the Gambusia affinis, belonging to the family Poelicidae, have been found to be effective in the de-

struction of anopheles larvae. Experiments with fish of this variety and of other surface feeders in other parts of the world have not proved as successful. This may be due to the presence of larger and predaceous fish and other aquatic enemies, to the existence of vegetation and other obstructions along the banks of streams under treatment, to inadequate food supplies capable of supporting sufficient fish life, and to a variety of other factors of human origin, but none the less effective.

Gambusia affinis, commonly known as the top minnow, flourishes best in brackish water, but thrives, also, in fresh water ponds and lakes. A medium sized female will devour as many as 165 large mosquito larvae in a day. In order to be effective it must be present in large numbers and the edges of the body of water in which it is introduced must be kept free of vegetation and other obstructions so that the fish may have easy access to the larvae. It is not effective in the control of yellow fever since the larvae of Aëdes egypti spend considerable time at the bottom of the water in which they exist.

Treatment of malaria. — Any discussion of the prevention and control of malaria would be incomplete without a brief statement of the use of quinin for treatment. Since malaria can exist only if anopheles mosquitoes can become infected by obtaining some of the blood from malarial patients or carriers who harbor the parasite, the importance of treating cases and carriers as one of the methods of control becomes obvious. Quinin was first introduced as a separate drug in 1810, but it was in use as an anti-malarial remedy as early as 1658 under the name of cinchona bark, also known as Peruvian or Jesuits' bark. It is used today as quinin sulphate, although there are other salts available. It is usually taken by mouth, although there have been advocates of the subcutaneous, intramuscular, and intravenous methods of injection. Plasmochin or synthetic quinin has also been employed as an anti-malarial drug, and its use has some advocates, but in general quinin obtained from natural sources is still commonly employed. The drug exhibits a specific toxic effect on the malarial parasite in the body.

The standard treatment for malaria recommended by the National Malaria Committee in the United States is as follows:

"For the acute attack (among adults) 10 grains of quinin sulphate should be taken by mouth three times a day for a period of

at least 3 or 4 days, to be followed by 10 grains every night before retiring for a period of 8 weeks. For infected persons not having acute symptoms, only the eight weeks treatment is required." The proportionate doses for children are as follows:

Under 1 year	0.5 grains
1 "	1.0 "
2 years	2.0 "
3 and 4 "	3.0 "
5, 6, and 7 "	4.0 "
8, 9, and 10 "	6.0 "
11, 12, 13, and 14 "	8.0 "
15 years and over	10 0 "

While this treatment does not cure 100 per cent of the cases, if followed conscientiously, it will cure over 90 per cent of the patients. Relapsing cases of malaria should be treated as new cases. In order to be most effective the treatment should be initiated as soon as the first symptoms appear.

Blackwater fever. — This disease occurs frequently in the tropics, and to some extent in the southern part of the United States and in Europe, and is now believed to be a malignant form of estivo-autumnal malaria. It is accompanied by fever, bloody urine, a marked breakdown of the red blood corpuscles, delirium, and collapse. It ends frequently in coma and death.

Yellow fever. Historical. — It is difficult for those who are alive today to realize that yellow fever, a disease characterized by jaundice and hemorrhage, was formerly one of the most widespread and devastating that affected man. In the brief span of one generation it has been eliminated gradually first from one pest hole, then from another, until at present there are only two main foci, Brazil and the West Coast of Africa. The successful conquest of this disease is due very largely to the graphic demonstration that it is transmitted from one individual to another only through the bite of the Aëdes egypti, the yellow fever mosquito. This noteworthy contribution to sanitary science and public health was made by the U.S. Army Medical Commission in 1901, appointed for the purpose of studying the etiology and control of yellow fever in Havana. As a result, yellow fever was banished from Havana; subsequently, from the Isthmus of Panama; and later from numerous other areas.

Although yellow fever is supposedly a disease that flourishes only in tropical or subtropical countries, it is important to remember that epidemics of the disease have occurred in temperate regions as well. For example, Boston had epidemics of yellow fever in 1691 and 1693. New York had an epidemic in 1668, and according to Dr. Charles Bolduan of the New York City Department of Health, yellow fever was epidemic in New York City thirteen times between 1791 and 1807. In consequence, New York lost almost 10 per cent of its population. The malignant epidemic of 1702 was supposed to have been "brought to the city in a bale of cotton from St. Thomas, West Indies." The last epidemic of yellow fever which affected New York occurred in 1870.

Other important cities in the United States also suffered seriously from yellow fever. In 1793 Philadelphia experienced such a serious epidemic that one in every ten of the population succumbed to the disease. Baltimore had an epidemic in 1819, and yellow fever was especially prevalent in the southern states, including the lower Mississippi River valley. New Orleans, the gateway from the tropics to the United States, was one of the greatest sufferers from yellow fever and experienced an epidemic of this disease as recently as 1905. In 1901 Reed and Carroll of the U.S. Army Medical Corps estimated that between 1793 and 1900 there had been not less than 500,000 cases of yellow fever in the United States.

The occurrence of yellow fever in a community always caused great havoc and consternation as well as serious economic loss. Quarantine was rigidly enforced and fomites including the patient's bedding, clothing, baggage, toys, books, and other objects were thoroughly disinfected. Even mail and freight were disinfected. Yet the disease continued to flourish and nothing seemed able to check it except the oncoming of heavy frosts. The disease always prevailed during warm, rainy weather, and always abated with the approach of cold weather. It seemed to be entirely beyond human control.

Studies in etiology and mode of transmission. — As early as 1881, however, Dr. Carlos Finlay of Havana, Cuba, had published a paper suggesting that mosquitoes were responsible for the transmission of yellow fever, but it was a long way from theory to established fact. In 1900, while the United States Army was stationed in Cuba, an epidemic of yellow fever broke out in Havana.

The Americans had transformed the city into a model of sanitary cleanliness, but in spite of this the disease continued to prevail. Accordingly an Army Medical Board was appointed to study its etiology and control in Cuba. Dr. Walter Reed was placed in charge, and associated with him were James Carroll and Jesse W. Lazear, two American Army physicians, and Dr. Aristedes Agramonte, a Cuban physician who had had yellow fever and was therefore immune.

One of the prevailing theories at the time was that yellow fever was due to an infection with Bacillus icteroides isolated by Sanarelli, an Italian physician. Examination of numerous cases of yellow fever during various stages of the disease and after death failed to show the presence of this organism either in the blood or organs of the body. Accordingly the American physicians turned to the Finlay theory that yellow fever was mosquito-borne, and this view must have received added credence in the light of Ronald Ross' recent work on the life cycle of the malarial parasite in the body of the anopheles mosquito. At any rate, Dr. Carroll and another volunteer allowed themselves to be bitten by mosquitoes that presumably were infected. Dr. Carroll was bitten by a mosquito that had been allowed to feed on four patients suffering from yellow fever. The interval between the first yellow-fever-blood meal and the voluntary exposure to the mosquito bite was 12 days. Both volunteers had never had yellow fever and were therefore considered to be susceptible to the infection. Three days after he was bitten Dr. Carroll came down with a typical attack of yellow fever and for the next three days it was uncertain whether he could survive. The second volunteer had been bitten by four mosquitoes, two of which had obtained blood from fatal cases of yellow fever twelve days previously, one of which had bitten a severe case of the disease during the second day of illness sixteen days previously, and one which had bitten a severe case of yellow fever eight days earlier. Five days after exposure the second volunteer also developed yellow fever, but his attack was comparatively mild.

In the meantime, Dr. Lazear, another member of the yellow fever commission was bitten accidentally by a mosquito while he was collecting blood from yellow fever patients for study purposes. Five days later he developed the typical symptoms of yellow fever which unfortunately proved to be fatal.

Evidence was now available to incriminate the mosquito as the probable vector of yellow fever. It was necessary, however, to demonstrate this fact under conditions that were rigidly controlled and which would rule out other possible vehicles of the infection. Accordingly, two small buildings, one story high, and fourteen feet by twenty feet in surface dimensions, were constructed in an open field near Quemados, Cuba. One structure was designated as the infected clothing building and the other as the infected mosquito building. The infected clothing building was poorly ventilated but was thoroughly screened against the possible entrance of mosquitoes. Into this building were brought sheets, pillow cases, blankets, and other articles contaminated by contact with yellow fever patients and their discharges. Many of the articles were purposely soiled with the black vomit, urine, and fecal matter of the yellow fever patients. All of these steps were taken to ascertain whether fomites soiled with the secretions and excretions of yellow fever patients were involved in the transmission of yellow fever.

Three volunteers, each non-immune, unpacked all the articles and made up the beds. As each article was picked up it was shaken vigorously in order to infect the air, if any infection were present. They also slept in the beds for a period of 20 days. The experiment was repeated three times with other volunteers, and in spite of the fact that they slept in garments that were soiled by fatal cases of yellow fever, not the slightest symptom of the disease occurred among any of them. It seemed obvious, therefore, that fomites were not involved in the transmission of yellow fever.

A totally different story was being unfolded in the infected mosquito building. Here the ventilation was very satisfactory and the bedding was thoroughly disinfected. The building was also carefully screened, not for the purpose of keeping mosquitoes out, but largely in order to keep the released infected mosquitoes in. Through the middle of the room ran a mosquito-proof screen.

On December 5, 1900 a non-immune volunteer who had been in quarantine for fifteen days and who had had no other possible exposure, allowed himself to be bitten by five mosquitoes that had been permitted to feed on yellow fever patients fifteen or more days previously. At the end of three days and nine and one-half hours he developed the typical symptoms of yellow fever. The experiment was repeated, and in all, ten cases of yellow fever were produced by allowing volunteers to be bitten by infected mosqui-

toes. Positive proof of the infectivity of the mosquito seemed to have been established, but the commission carried the proof one step further. Other volunteers, who were also non-immune to yellow fever, were allowed to sleep in that portion of the infected mosquito house that had been segregated by the use of a mosquito-proof screen. These volunteers, therefore, breathed the same air as the experimental group and they were kept under identical conditions, except that they were not allowed to be bitten by infected mosquitoes. Not a single case of yellow fever developed among them. The proof was complete.

In spite of the fact that it has been established that yellow fever is transmitted naturally only through the bite of the infected yellow fever mosquito, information concerning the nature or identity of the parasite responsible for the infection has as yet not been obtained. In 1919, Dr. Hideyo Noguchi of the Rockefeller Institute for Medical Research announced that yellow fever was due to an organism called the Leptospira icteroides, but this observation has never been confirmed. Today (1934) the etiological agent is still unknown, but the supposition is that the parasite is a filterable virus. In order to study the problem in an area where yellow fever was endemic the British established a Medical Research Institute at Accra, Gold Coast, West Africa, and the Americans, through the medium of the International Health Board of the Rockefeller Foundation, established a laboratory at Lagos, Nigeria, West Africa. Unfortunately, four distinguished scientists lost their lives in these experiments, two British and two Americans. On May 21, 1928, Dr. Hideyo Noguchi died of an accidental yellow fever infection, and on May 30, 1928, Dr. W. A. Young, Director of the British Medical Research Institute at Accra, succumbed in the same way. The etiology of yellow fever is therefore still an unsolved mystery.

Incubation and infectivity periods. — Among the significant contributions resulting from the studies of the U.S. Army Yellow Fever Commission were the demonstrations that definite periods must elapse before the human host and the yellow fever mosquito are able to infect each other. In the case of the human host, infection can be transmitted to the mosquito only during the first three or four days of the disease. After the mosquito becomes infected, a period of at least twelve days must elapse before it is capable of transmitting the infection to man. Presumably the time is required

for the maturation of the yellow fever parasite in the body of the mosquito. Once the mosquito is infective, however, it remains in that condition probably for the remainder of its life. In the experiments conducted by the U.S. Army Yellow Fever Commission, two of the mosquitoes transmitted the disease to a volunteer 57 days after they were infected. Once infected, therefore, a yellow fever mosquito may infect numerous individuals.

Yellow fever mosquitoes. — The mosquito which has always been associated with yellow fever is the Aëdes egypti. It was first known as Stegomyia fasciata; later as Stegomyia calopus; later still as Aëdes calopus, but its currently accepted name is Aëdes egypti. It is only moderate or small in size, the female measuring 3.3 to 5 mm. in length, and the male, from 3 to 4.5 mm. In general, its natural habitat is confined within the belt between 40° north latitude and 40° south latitude, extending completely around the world. It is found abundantly in most of our southern states and in Cuba, in spite of the absence of yellow fever. Similarly, it abounds in Hawaii, Australia, the Philippines, and in Asia even though yellow fever is absent in those areas. This situation illustrates the importance of keeping yellow fever out of these countries for, with such enormous reservoirs of susceptible humans, the development of any focus of infection in their midst might lead to a staggering loss of life. With the airplane and ocean liner knitting even the most distant and unfrequented areas of the earth closely together, the price of safety against yellow fever and other tropical diseases must be eternal vigilance. The absence of yellow fever in large areas where yellow fever mosquitoes prevail illustrates once more that in order for the disease to prevail it is necessary to have infected humans and infected mosquitoes.

Aëdes egypti is dark or reddish brown in color with characteristic body markings. The thorax has a conspicuous, broad, silvery-white curved line on each side, with two parallel silvery lines in between. Between these straight lines there runs an indistinct, slender, broken line. These markings give a lyre-shaped appearance to the thorax. The abdomen is dark but is encircled with silvery-white bands at regular intervals. On each side of the abdominal segments there is a silvery-white spot. The legs are also characteristically marked, being black in color but possessing rings of pure white at the tarsal segments. The palpi of the male are either equal in length with the proboscis or are only slightly shorter,

whereas in the female the palpi are uniformly less than one-half the length of the proboscis.

Aëdes egypti is a domestic mosquito. It breeds in and around the house in rain barrels, cisterns, tin cans, broken bottles, broken crockery, flower vases, holy water fonts in churches, roof gutters, and any other receptacle used for holding water near the habitation of man. Under favorable conditions the life cycle, from egg to adult, is completed in from twelve to fifteen days. Under unusually favorable conditions of temperature the American Army Commission in Cuba found that the life cycle could be completed in 9.5 days. Under less favorable conditions the time required may be greatly prolonged.

Aëdes egypti is preëminently a day mosquito, in direct contrast to the anopheles mosquito. It feeds most actively about sunrise and also late in the afternoon. On cloudy days it will bite at any time of the day. The optimum temperature for biting is between 27° and 30° C. (78° and 86° F.). It is a very wary insect, approaching its prey stealthily and silently from behind and retreating immediately on the slightest alarm. A favorite point of attack is either the ankle or the underside of the wrist. It hides a good portion of the time, concealing itself in the pockets and folds of clothing in closets, or under the lapels of coats. In the house it will hide in dark corners, under moldings, and behind the heads of old-fashioned bedsteads.

Campaigns against Aedes egypti must take into consideration the life cycle and habits of the mosquito. All actual and potential breeding places in the vicinity of the home must be located and eliminated. Effective screening is also essential, and likewise the destruction of mosquitoes found in the house. Cases of yellow fever developing in a community must be isolated in a mosquito-proof room immediately, and the infected room or house thoroughly fumigated to destroy any infected mosquitoes that may be present.

In recent years other mosquitoes than Aëdes egypti have been associated with the transmission of yellow fever, notably in West Africa. As a result of studies made by J. H. Bauer of the International Health Board of the Rockefeller Foundation in 1928, Aëdes luteocephalus, Aëdes apicoannulatus, and Eretmopodites chrysogaster have been found capable of transmitting yellow fever under laboratory conditions. Other mosquitoes subsequently found capable of transmitting yellow fever include Aëdes africanus,

Aëdes simpsoni, Aëdes vittatus, and Taeniorhynchus africanus. In the International Health Board studies it was also found that the Indian monkey, Macacus rhesus, was susceptible to yellow fever. This fact is exceedingly significant for it means that yellow fever may be kept alive as a potential threat against humans by its existence in an animal species. Studies made at Lagos also showed that the blood taken from an infected monkey at the onset of fever contained sufficient virus to cause fatal yellow fever if rubbed on the unbroken skin of a normal monkey. This illustrates the hazard confronting laboratory workers engaged in the study of the etiology of yellow fever and the importance of avoiding accidental infection.

Dengue fever. — In 1902, Graham, working at Beirut, demonstrated experimentally that dengue fever, also known as breakbone fever, is transmitted to man through the bite of a mosquito. The insect involved is the Aëdes egypti. Besides showing that dengue fever can be transmitted to susceptible humans by allowing them to be bitten by infected mosquitoes, Graham transported the infected mosquitoes to a mountain village known to be free of dengue fever and there succeeded in infecting two volunteers who allowed themselves to be bitten. The disease is endemic in the Philippines and in some of the Pacific islands. Extensive epidemics have occurred, however, in southern Europe, Asia, and the United States. In the latter country, serious epidemics occurred in recent years, in Florida and Texas. In Texas alone, it is estimated that there were between 500,000 and 600,000 cases in 1922. The disease is rarely fatal.

Dengue fever is characterized by severe rheumatic pains in the muscles and joints, by intense headache and pain over the eye, and frequently, in the later stages of the disease, by a skin eruption, followed by scaling. The disease is accompanied by pronounced prostration. After three or four days it subsides, but there is a recurrence on the fourth to the sixth day. The symptoms of dengue fever are suggestive of mild attacks of yellow fever, and although the two diseases are transmitted by the same insect, the identity of the parasites involved has not been established. The incubation period of the dengue fever parasite in Aëdes egypti is believed to be at least 8 days. The infectivity of the mosquito lasts for a long time, but its ability to transmit the infection depends on the temperature. A minimum temperature of 22° C. (approximately

72° F.) is necessary to make the insect infective. Other species of Aëdes may also be capable of transmitting the disease, and at least two species of macacus monkeys are known to be susceptible to dengue fever, and may therefore be reservoirs of infection for man.

Filariasis. — This disease, transmitted by the mosquito Culex fatigans, occurs in the tropics and subtropical countries and only occasionally in the United States, in the southeastern area. The disease is due to an infestation of the connective tissues, lymphatics, and body cavities of man with the adult and larval forms of long, slender, thread-like worms possessing a curved tail, and known as filaria. Filaria bancrofti, loa, and pustans and their larvae are the responsible parasites. The control of the disease consists in the effective eradication of mosquitoes and their breeding places.

CHAPTER XIX

RATS AND THE PUBLIC HEALTH

Reasons for combating rats. — The economic and public health significance of the rat is generally not appreciated. Otherwise, action against this dangerous pest would be more consistent, vigorous, and continuous. At present it requires the stimulus and alarm of a threatening epidemic of plague to galvanize community interest into action against this common enemy. Yet the rats are of interest to man not because of plague alone, but because of other diseases as well, and also because they destroy property, food, and merchandise of almost inestimable value each year. It is estimated that in the United States alone the destruction due to rats and mice measured in monetary value would approximate $200,000,000 per year.

Varieties of rats. — In addition to the common house mouse three varieties of rats have established themselves in the United States. Of these the most important is the brown rat, the one involved in the transmission of plague in the United States. It is also known as the Norway rat and is spoken of technically as Rattus norvegicus. It is also the predominant rat in Europe. Other specfes are the black rat or Rattus rattus, the common rat of India and other parts of the world, and the Egyptian rat, or Alexandrian rat, known technically as the Rattus rattus alexandrinus which has spread from Egypt to many parts of the world and especially in the tropical and subtropical regions.

Habits of the brown rat. — The brown rat frequents barns, wharves, stables, markets, and sewers as well as houses, is larger and more ferocious than the other two species, and has become ascendant in the struggle for survival. It is very destructive, lives in burrows, and is exceedingly prolific. Their numbers are limited only by the available food supply. Ordinarily from three to five litters will be produced in one year, the number of young varying each time from six to nine, but occasionally as many as twenty-two or twenty-three young rats may be produced at one time. An anti-rat campign aiming at the general destruction of rats merely makes

it possible for those that escape to survive more readily and bountifully. While this should not be construed as an argument against rat eradication, it illustrates the difficulty of exterminating a biological species, especially one that breeds as prolifically as the rat.

The rat problem in India and East Africa. — The number of rats in the world is doubtless enormous, and they must rival the human species in population. Various anti-rat campaigns have yielded almost incredible numbers of rats. In two districts of India, following the onset of famine caused by depredations of food accomplished by rats, a reward was offered for their destruction, and over 12,000,000 were killed. Professor W. J. Simpson in his *Report on Sanitary Matters in East Africa* also describes an incredible catch of rats following a campaign in Muanza, East Africa. The population consists of primitive Africans living in round huts having mud walls and grass roofs. The staple food of the natives is grain, and this is stored in small grass-roofed granaries in close proximity to their huts. This creates an ideal situation for the rodents, the average rat population per hut being fifteen. On one occasion as many as sixty rats were destroyed in one hut. Under such conditions it is not surprising to learn that during a period of ten weeks when an active anti-rat campaign was conducted, 1,100,000 rats were destroyed. Of this number 10,000 rats were examined and 4 per cent were found to be infected with plague. Since rats invade ships of all kinds they are great travelers and infest the routes of commerce to all parts of the world. Accordingly, it is impossible for the more civilized people to ignore conditions such as those existing in India, Manchuria, North China, or East Africa. The most dreaded disease spread by rats is plague, and this disease must be fought at its source or it will spread rapidly and with devastating effect to other parts of the world exactly as it did during the Middle Ages. The Great Plague of London which occurred in 1665 was due to rat plague, and of a population of 460,000, approximately 70,000 people, or one in every six or seven, died. The average life of a rat is estimated to be about two years.

The rat and its ability to survive. — One of the reasons why it is difficult to combat the rat more successfully is its ability to survive on such a varied diet. It eats almost anything and everything, including grains, seeds, and their derivative food products; vegetables, fruits, milk, butter, cheese, meat, fish, eggs, chickens, duck-

lings, squabs, and other foods used by man. It forages between sundown and sunrise when depredations can be made with greater safety. While the brown rat lives mostly in burrows located in cellars, a fact that makes his eradication more difficult, the Egyptian rat and the black rat live in the walls of buildings or in the spaces near the roof, and in the tropics they frequently make their nests in trees. Rats are clever, intelligent, and wary. They are equipped with unusual ability to survive under varied conditions. The control of these pests therefore requires the best intelligence and ingenuity which can be brought to bear on the problem.

Public health significance of rats. — The relationship of rats to plague in man has been indicated above, and its significance as a disease has been recognized for centuries. It should be understood, however, that plague is primarily a disease of rodents and only secondarily a disease of man. People residing in plague infected areas have often noticed the occurrence of an epizootic among rats before the disease made its appearance among humans. An explanation is found in the fact that the rat flea, which sucks blood, leaves its normal host when he dies and the number of rats becoming greatly diminished, he then attacks man. That the rat flea transmits plague from rat to rat was demonstrated by Simond in 1898. Since then the British Plague Commission in India has shown that plague is transmitted by the rat flea from rats to guinea pigs and from rats to monkeys. While there is no experimental evidence to prove that bubonic plague is transmitted to man by the rat flea, there are definite cases of accidental laboratory infection obtained in this way, so that no reasonable doubt exists any longer concerning the mode of spread of bubonic plague. Nevertheless, since bubonic plague is caused by a bacillus — the Pasteurella pestis, discovered by Yersin in 1894 — and since it is not necessary for this organism to pass through the body of the flea in order to complete its life cycle, there may be other ways of transmitting the organism to man. In fact, in the pneumonic form of plague the disease may be transmitted from man to man by contact infection, while in bubonic plague, the bedbug has also been incriminated. Head lice obtained from a human case of plague and body lice obtained from infected squirrels have shown the presence of living plague bacilli. While it is doubtful whether plague originates in this way to any degree, it is important to remember that any blood sucking insect has the potentiality, at least, of transmitting

plague infection. Infected food may be a vehicle of plague infection only if there is a lesion in the alimentary canal through which the organisms may gain entrance into the body proper.

It must be concluded therefore that the rat flea is the principal vector of plague for man, as even in the case of pneumonic plague, the original case probably arises from some rodent through the agency of the flea. The India Plague Commission demonstrated in a variety of ways that the flea is well-nigh essential in the transmission of plague from rats to rats, from rats to guinea pigs, and from rats to monkeys. Contact with plague infected animals and with their excretions was not enough to transmit plague to the healthy, experimental animals if fleas were eliminated. On the other hand if fleas were present and their effectiveness was not vitiated then the disease spread rapidly from the infected to the experimental group of animals. Aerial infection was eliminated even in the presence of fleas by elevating some of the test animals two feet above the ground. Similar animals allowed to run about on the ground or elevated only two inches above the ground became infected. It was demonstrated that fleas jump from three to five inches and never over six inches so that it was possible to protect the test animals by elevating them sufficiently above the floor. Similarly the test animals could be kept on the floor with impunity, if they were surrounded with a sticky substance capable of entangling the flea and keeping him at a safe distance. Without this protection the animals frequently developed plague and died.

The biology of the rat flea. — Since Pasteurella pestis, the cause of plague, does not undergo part of its life cycle in the rat flea, there is not quite the same urgency to study the life cycle of the insect as there was in the case of the malarial mosquito. Nevertheless, since plague is transmitted primarily by the flea, a knowledge of its habits, characteristics, and life cycle is essential to combat it effectively.

The flea is a wingless insect, about two to three millimeters in length, and possesses a hard, chitinous outer envelope. In its development it passes through the egg, larval, and pupal stages before it reaches the imago or adult form. The life cycle is usually completed in about eighteen to twenty-one days although under favorable conditions of temperature and moisture the cycle may be accomplished in about ten to fourteen days. No portion of the cycle is aquatic. The larvae feed on the organic matter in house-

hold dust and other refuse, and molt three times during this stage. Both the male and female are able to pierce the skin and obtain blood, so that both sexes are involved in the transmission of plague. Since plague is not limited to rats alone, but affects other rodents as well, the disease may be transmitted by a variety of fleas. In 1908 it was demonstrated that plague in California had spread from rats to ground squirrels (Citellus beecheyi), and evidence was also found to show that the Siberian marmot or tarbagan (Arctomys bobac), an animal related to the ground hog and hunted for its fur, is also susceptible to plague. In fact it is believed that the devastating epidemics of pneumonic plague which affected Manchuria and Northern China in 1910 to 1911 and in 1920 to 1921 had their origin in the prevalence of plague in the Siberian marmot. The existence of plague among the ground squirrels of California creates a reservoir of infection which makes the elimination of plague exceedingly difficult. An infected squirrel is believed to have been responsible for the small epidemic of pneumonic plague in Oakland, California, in 1919. Since rats live in the same environment with ground squirrels, plague can be transmitted quite readily from squirrels to rats and vice versa, and eventually to man.

Since plague is a disease of rodents primarily, the flea that is capable of attacking man as well as rodents may be a transmitter of plague. As a result, various fleas have been involved in the transmission of plague, but the one commonly observed in most epidemics has been the India rat flea, Xenopsylla cheopis. Although this flea is supposedly of Asiatic origin, it has become widely distributed, and, in the United States, has been found quite regularly in seaport towns. Xenopsylla astia and Xenopsylla braziliensis are also widely distributed and are likewise able to transmit plague, but they are not as effective as Xenopsylla cheopis. The common rat flea in North America and Europe is the Ceratophyllus fasciatus which is also able to transmit plague. Other fleas known to be able to transmit plague include the ground squirrel flea, Ceratophyllus acutus, and the tarbagan flea, Ceratophyllus silantievi.

One of the numerous questions concerning plague is the mechanism by which the flea transmits the infection to man. Apparently infection is accomplished in two ways. It had been observed that while the flea is feeding it habitually squirts blood through the anus and that if the insect had fed on plague infected rodents the

blood contained large numbers of Pasteurella pestis. Since the blood is retained in the stomach for some time it serves as a culture medium, resulting in a material multiplication of the plague bacilli that are ingested. When the blood containing plague bacilli is discharged through the anus, a film containing virulent bacilli forms on the underside of the flea and organisms are actually inoculated in the process of biting. The bite also stimulates scratching and infection may also take place readily in this way.

Infection may be transmitted by still another method. It was observed that the oesophagus and proventriculus of the infected flea may become so clogged with plague bacilli that the opening to the stomach may become plugged. As the blood sucking apparatus is in the pharynx the flea continues to suck blood and as it is not getting the benefit of its nutriment, it becomes rather persistent in its efforts to obtain blood. While sucking blood under these circumstances, part of the blood in the occluded portion of the alimentary canal is regurgitated, and infection may be introduced directly into the body of the temporary host in this way.

Fleas may be destroyed quite readily in a variety of ways. Kerosene, and tincture of green soap, for example, are very effective, but water, glycerin, formalin, phenol, mercuric chloride, and tricresol are not. Fleas are also destroyed quite readily by fumigation, hydrocyanic acid gas being most efficient since it destroys both the eggs and the fleas. Sulphur dioxide gas is likewise effective but it cannot be relied upon to destroy the eggs. Chloroform and ether anaesthetize the flea, and if applied for a sufficient period, destroy them. The larvae in flea-infected houses can be destroyed by sprinkling the floors heavily with flake naphthalene and keeping the room tightly shut overnight. The naphthalene may be swept up the following morning and used over again.

Varieties of plague.—There are three forms of plague in man, (1) bubonic, (2) pneumonic, and (3) septicemic. Of these the most important is the bubonic form, for it represents about 80 per cent of the human cases. Both the bubonic and septicemic forms are transmitted largely through the bite of the flea, and while the pneumonic form may have had its origin in the same way, the fact that the bacilli of plague are found abundantly in the sputum of such cases indicates that this form of plague is communicable from man to man by contact infection.

Foci of plague infection. — Since 1900 four foci of infection have developed in the United States. In that year 22 cases occurred in California, the first known cases occurring in San Francisco. The local authorities refused to admit the existence of plague for seven years and this unfortunate delay made it possible for the infection to spread to the ground squirrels. As a result, the elimination of the infection is destined to be exceedingly difficult. In 1907 there were 170 cases of plague in California and it was not until the Federal health authorities threatened to quarantine the entire state that the existence of plague was admitted and control measures instituted. Since then plague has occurred at New Orleans (1914), at Beaumont and Galveston, Texas (1920), and in Florida (1920). Plague has also occurred in other parts of the western hemisphere, including Brazil and Puerto Rico. Other and more serious foci of infection exist in China and Manchuria, India, Serbia, and Arabia, and Uganda and Kenya in Africa.

Control of plague. — The prevention and control of plague represent a difficult, time-consuming, and expensive procedure, for they consist primarily in the elimination of rats and fleas. In the pneumonic type, direct contact with patients must also be avoided except by doctors and nurses. In India, Dr. Haffkine of the British Plague Commission succeeded in developing biological methods for producing an active and passive immunity, and in this way has afforded temporary protection against plague to millions of individuals. The passive immunity, produced by utilizing anti-plague serum, lasts only from three to four weeks, while the active immunity, produced by vaccination with killed cultures of plague bacilli, lasts about six months. While temporary relief against plague can be obtained in this way during an epidemic, permanent or durable protection can only be obtained by waging a successful war against the rat, and in that way against the rat flea.

Numerous methods have been devised for destroying rats, but their extermination is well nigh hopeless. Those on a ship, or in a stable, warehouse, granary, or market may be destroyed by thorough fumigation. Their numbers can be reduced perceptibly at least for a brief period, and this may be sufficient to control the epidemic of plague for which they are responsible. Anti-rat measures consist first of all in attempting to keep them out of

buildings and dwellings, and second, in starving them out by keeping all food away from them. Therefore the rat-proofing of all buildings, piers, warehouses, dwellings, and other places of human abode or food storage is absolutely essential. For this purpose concrete or cement foundations of suitable thickness, depth, and height are desirable, and all possible avenues for entrance into the building from the outdoors must be thoroughly protected. Within the house all unused food must be properly protected, while garbage, slaughterhouse wastes, and other edible organic refuse must be stored in rat-proof containers and disposed of in such a way that rats will not be sustained by the remains.

In addition to the above procedures for keeping out the rat and preventing his propagation, measures must also be taken to destroy him. This may be accomplished by using traps, poisons, domestic animals, and fumigants. Trapping is effective if used intelligently, with due regard to the habits and craftiness of the rat, with adequate attention to eliminate all traces of human handling, and with suitable bait. After the rats are caught they can be dipped in kerosene to destroy the fleas that are on them, and then killed and examined for evidences of plague. They and their associated fleas may also be destroyed by using ether or chloroform in a sealed chamber.

Poisons are of two varieties, biological and chemical. The biological poisons are mostly bacterial and consist either of cultures of B. typhi murium, Salmonella paratyphosus B, or Salmonella enteritidis. Not only do these cultures lose their virulence on exposure to light and air with the passage of time, and therefore suffer in effectiveness, but foods inoculated with them may serve as foci of infection of human food through the medium of rats and mice. Their use, especially that of S. parathyphosus B, is therefore of some danger to man and of limited value in the elimination of rats. Their general use in homes and public buildings is therefore not recommended, but in certain cases, *i.e.*, barns and cellars, they may be quite effective.

Chemical poisons, properly prepared and rightly used, are very effective. One serious objection to their use, especially in dwellings, arises from the odors of decomposition resulting from dead rats that cannot be reached and therefore removed. Poisons are used therefore primarily on dumps and wharves, and in stables, granaries, or other places not reserved for human habitation and

which are difficult or expensive to make rat-proof. The principal poisons are barium carbonate, strychnin, arsenic, and phosphorus. Barium carbonate is perhaps the best. Phosphorus is effective but is associated with a fire hazard. Strychnin is also effective, while arsenic, which is used extensively, is employed as arsenious acid. The use of poisons is fraught with danger for humans as well as domestic animals. Unusual precautions must therefore be exercised to eliminate all possible danger except for the rat.

Domestic animals are of little avail against the rat. Some dogs are effective in keeping a dwelling free of rats, but cats are either too lazy, too well fed, or too fearful to be of any value in an anti-rat campaign. There are other natural enemies of the rat, but these, like the fox, coyote, weasel, hawk, and owl, are not available under urban conditions.

Fumigation is an exceedingly important anti-rat and anti-plague measure. As rats are great travelers, they pass from one country to another in the holds of ships, and perhaps the only effective and reliable method of reaching them is by fumigation. Incidentally, it is one of the most effective methods of protecting a community against infection when a ship arrives from an infected port. Fumigation may also be used to destroy rats in cellars, in their burrows, in stables, warehouses, and other places where they may exist in large numbers. The gases used are either hydrocyanic acid gas, sulphur dioxide, carbon bisulphide, or carbon monoxide. Although carbon bisulphide is liquid at ordinary temperatures, it volatilizes quite readily and produces its destructive effect by asphyxiation. Carbon monoxide and carbon bisulphide are both inflammable and must be used with caution. When a vessel is fumigated all hatches must be closed and care taken to exclude all humans. After fumigation is completed, the hold of the vessel should be thoroughly ventilated. Small birds like canaries are sometimes used as test animals to ascertain whether the air is fit for human habitation. When buildings are fumigated all doors and windows should be sealed and suitable precautions observed before they are occupied again. Fumigation with sulphur dioxide or hydrocyanic acid gas destroys not only the rats, but likewise the fleas that may be on them. Because of the possible damage to the cargo sulphur dioxide gas cannot always be employed. Ships leaving plague infected ports should be fumigated when empty, and again before arrival at the port of debarkation.

When anchored, the vessel should have all lines and hawsers protected by large metal discs, three feet in diameter, placed at right angles, or large metal funnels, which will prevent the passage of rats to and from the ship. Domestic animals, like cats and dogs, should also be washed in kerosene before they are allowed to come ashore in order to kill any fleas they may be carrying.

Other diseases associated with the rat. — Among the diseases other than plague associated with the rat and which are of importance to man, are acute infectious jaundice, trichinosis, and food poisoning. Rat bite fever and certain parasitic infections other than those mentioned may be included, but they are of minor significance.

Infectious jaundice achieved considerable prominence during the World War because of its prevalence among front line troops. Like bubonic plague it is a disease primarily of rats and secondarily of man. It is caused by the Spirochaeta or Leptospira icterohaemmorhagiae In the World War the fatality rate was only about 2 or 3 per cent, but in Japan the disease is more prevalent and likewise more fatal, the fatality rate being as high as 38 per cent. Infection in man probably occurs through the skin and is the result of contact with moist soil infected with the urinary discharges of rats suffering from the disease. Apparently the disease is not spread from man to man. Prevention consists in rodent destruction, protection of food against rodent contamination, the wearing of shoes, and general personal and environmental cleanliness.

Trichinosis in man is derived exclusively from the eating of uncooked meat, especially pork, but since the rat is a reservoir of trichinosis, and hogs sometimes eat rats, infection among hogs, and therefore among man, is kept alive in this way. Hogs may also become infected through the consumption of infected garbage or other organic refuse used as hog food. The disease is caused by the Trichinella spiralis. Prevention consists in rat eradication in slaughterhouses, hog pens, butcher shops, and restaurants, the inspection of meats and the thorough cooking of all pork products before they are consumed.

Food infections with organisms of the Salmonella food poisoning group have been known to occur through the medium of rats and mice. Here, too, the remedy is the elimination of rodents and the protection of foods against infection.

CHAPTER XX

FLIES AND THE PUBLIC HEALTH

The fly in relation to disease. — With the increase of knowledge leading to the incrimination of insects as vectors in the transmission of disease, several types of flies, including the common house fly, have been found to be of distinct significance, and the attitude of the enlightened public has changed from toleration of an annoying but omnipresent summer nuisance to open warfare against a potential source of danger. In the past three decades much has been said and written about the broad relationships of flies to public health. In many communities public campaigns against the fly have been organized, articles have appeared in the press, cartoons have stimulated the public anxiety, and whole states have been made fly conscious. It is well recognized that flies are filthy insects and may play a part in the transmission of disease, particularly in unsewered communities, yet it is probably correct to say that in the United States their relationship to disease has been somewhat exaggerated. Undue overemphasis on the rôle of the fly in the transmission of disease should not be allowed to detract from the greater and continuous importance of infection by human contact as well as through water, milk, and other foods. At present, in most parts of the United States, flies probably play a minor rôle in the transmission of disease in comparison with the vehicles just enumerated. It is true, however, that in rural villages and unsewered communities, especially in the sections with a long, fly breeding season each year, the importance of the fly as a vehicle of disease is notably increased. Even under such circumstances, and under usual peace-time conditions, fly-borne disease is secondary in importance to the transmission of disease by other methods.

This point of view is in no sense an argument in favor of the abandonment of any anti-fly activities. On the contrary, efforts to suppress the fly should be continued, first because the common fly may at any time become a vehicle of disease, and second, because their presence in the house or elsewhere is a nuisance

which violates the sense of personal, domestic, and public cleanliness which has gradually been built up in civilized populations. Conditions which permit flies to swarm around our foods, to invade our kitchens and nurseries, to congregate in fruit stalls and meat markets, or to find their way into the milk pails in barns and dairies are objectionable aesthetically, even though they may not have vast public health significance. There is also no question that flies promote food spoilage by the bacterial and fungus contaminations which they impart.

There are two ways in which flies, all of which belong to the order of Diptera, or two-winged insects, may be involved in the transmission of disease; first, by the mechanical transfer of pathogenic organisms to food, to open wounds, or to the skin, or exposed surfaces of mucous membranes; and second, by the direct introduction of specific parasites into the circulation through the piercing of the skin in biting. The ordinary house fly does not bite, because it is not equipped with biting apparatus, but Stomoxys calcitrans, the stable fly, which is very prevalent throughout the United States, the horse fly, and others, which are quite common in rural districts, can and do bite vigorously; and the Glossina flies, which are prevalent in Africa and are responsible for the spread of African sleeping sickness, are all able to pierce the skin of man and domestic animals. In the latter instance, the fly is a very important vehicle of disease, comparable in importance to the malarial mosquito. Every effort should be made to eliminate the insect, if this widespread and fatal disease is to be brought under effective control. In the United States, however, the chief concern is with the ordinary house fly, technically known as Musca domestica, and the stable fly, Stomoxys calcitrans.

Musca domestica. — This fly is probably the dominant house fly in most regions of the world. It breeds preferably in horse manure, but it can develop in almost any decomposing organic matter, including excrement of all domestic animals and of man, in garbage, decaying meat and vegetable matter, wet, dirty waste paper and refuse, moist sawdust sweepings, and other substances. Its breeding season is determined by the temperature, being continuous in the tropics, and rather prolonged in all the southern states of the United States. It is however very much shorter in the northern part of this country and in Canada. During the winter it survives in attics, closets, barns and stables, around

chimneys, in cellars, and in other sheltered, but cool places. It may also survive through the winter in one of its developmental stages. The marked reduction in the fly population during the fall of the year is believed to be due in part to a fungus infection caused by Empusa muscae, which is able to attack the fly when its resistance is lowered by the declining temperature.

As already indicated the fly is associated with filth. Not only does it breed in filth, but it hovers around decomposing organic matter. It feeds almost omnivorously on our choicest foods or on excrement, sputum, and putrefying organic refuse. It is especially attracted by milk and sugary and protein foods in general, and often seeks sores, open wounds, and healthy mucous membranes. When flies feed they frequently regurgitate or vomit material from the crop, and if these drops of liquid are allowed to dry they produce one variety of fly speck. Fly specks may also consist of fecal deposits. In either case thousands of bacteria may be deposited, and if the specks contain pathogenic organisms, infection may be possible. In addition, the feet and legs are rather hairy, and if they are heavily contaminated, as is easily done, the organisms transported in this way are distributed on the food, open sores, or healthy mucous membranes or other surfaces on which the insect may subsequently crawl.

The distance to which flies migrate has been a subject of considerable conjecture and some study. It was formerly believed that flies did not migrate far from their breeding places, and that they traveled at most a distance of one mile. Recent work has demonstrated, however, that flies, specially stained, could be recovered at a distance of six miles in less than 24 hours, and eventually at a maximum distance of over 13 miles, beyond the point of release. Flies do migrate, therefore, even though the proportion that travel far may be small. The distance traversed may be due in part to the search for suitable food supplies and breeding places, or in part to wind distribution.

Life cycle of Musca domestica. — Like the mosquito, the fly passes through four stages — egg, larva, pupa, and adult. Unlike the mosquito, however, the developmental stages are not truly aquatic, although moisture is essential. The eggs are laid in manure, garbage, or other decomposing organic refuse, in clusters containing about 120 to 150 single eggs. Each egg is about 1 mm. in length, pure white in color, and elongated rather than spherical.

It is difficult to determine accurately the egg laying capabilities of the female fly. Some have been observed to lay over 1,000 eggs during their lifetime, and in one instance, as many as 2,387 eggs were laid in a period of 31 days. It does not require much imagination to observe that if every egg developed into an adult female fly, and if every fly survived and propagated, the number resulting from one female fly alone at the end of the breeding season would reach into the trillions. Happily for man this condition is not attained in real life.

Under suitable conditions of temperature the eggs develop into larvae within 8 to 24 hours. The larvae, known also as maggots, are about 2 mm. in length, and are pointed at the head end and blunt at the tail end. They grow rapidly, molt three times, and attain maturity usually in 6 to 7 days. The pupal stage is passed in the last larval skin which is not shed, but which becomes toughened and protective. In this form, the outer covering is known as the puparium. The embryo remains in the pupal stage for a period between 3 to 6 days, after which it emerges as an adult fly. During suitable fly breeding weather, the life cycle may be completed within 10 to 12 days or somewhat less. In a climate comparable to that prevailing in Washington, D.C., as many as nine generations have been completed in one year under outdoor conditions. In warmer regions the number of generations would be increased, while in colder regions it would be less. The promptness with which newly hatched females begin to lay eggs is largely a function of the temperature and relative humidity. Copulation may occur within 24 hours after emergence, and the first eggs may be laid as early as 2.25 days after the adult is formed. The minimum time required for the first deposition of eggs under natural conditions varies from approximately 2.5 to 23 days.

Specific relationship of flies to disease. — The evidence that flies may transmit disease has been obtained both in the laboratory and in the field. Flies have been fed cultures of typhoid, tuberculosis, and anthrax bacilli, and viable organisms have been recovered in their dejecta. Living tubercle bacilli have also been recovered from the dejecta of flies allowed to feed on tuberculous sputum. In addition, cholera vibrios and living typhoid bacilli have been recovered from flies caught in the vicinity of outhouses where the excreta of diseased patients had been discharged. In

1903, Dr. Alice Hamilton isolated living typhoid bacilli from 5 out of 18 flies caught in two privies and on the yard fences, house walls, and room of a typhoid fever patient in Chicago. Living typhoid bacilli have also been recovered from the bodies of flies as long as 23 days after infection.

The most convincing and informative of the early demonstrations that flies may be responsible for the transmission of typhoid fever occurred during the Spanish-American War. Out of 107,973 men who were in the American army concentration camps in the southern states, there developed 10,428 definite clinical cases of typhoid fever and 10,310 probable cases of typhoid fever. In other words about one out of every five men contracted typhoid fever or some allied disease even though they were encamped only for six months (May–October, 1898). Of the number developing typhoid fever, 1,580 died. Greater fatality resulted from this cause than from losses inflicted in battle. A U.S. Army Medical Commission consisting of Drs. Reed, Vaughan, and Shakespeare, was appointed to study the prevalence of typhoid fever in the American camps during the summer of 1898, and, in a report submitted by Dr. Victor C. Vaughan, it is stated that "flies swarmed over infected fecal matter in the pits and fed upon the food prepared for the soldiers in the mess tents. In some instances where lime had recently been sprinkled over the contents of the pits, flies, with their feet whitened with lime, were seen walking over the food." While it is impossible to state exactly how much of the typhoid fever among American troops was contracted in this way, it seems apparent that wholesale fly-borne infection did take place.

Another graphic illustration of the rôle of flies in the transmission of typhoid fever and other intestinal diseases in unsewered communities, especially during the fly breeding season, is found in the experience of Jacksonville, Forida. In 1908, 1909, and 1910, the death rates from typhoid fever in Jacksonville were 82, 75, and 106 per 100,000 population, respectively. In August, 1910, through the effective action of the health officer, Dr. C. E. Terry, a city ordinance was enacted which required all privies in those sections of the city where sewers were not yet available to be made fly tight and to be adequately screened. By March, 1911, 75 per cent of the privies were fly tight, and by January, 1912, every privy in the city had been made fly tight. Although no

other anti-typhoid measure was introduced during the period under consideration, the typhoid fever death rate was diminished to 63 per 100,000 population in 1911, and to 26 in 1912. Whereas 110 cases of typhoid fever were reported in July, 1910, only 10 cases were reported in July, 1912.

In addition to typhoid fever, flies may transmit such intestinal diseases as paratyphoid fever, bacillary and amoebic dysentery, cholera, and diarrhea and enteritis. It is also reported that flies may play a part in the transmission of hookworm. Flies have also been incriminated in the transmission of purulent ophthalmia, infectious conjunctivitis or pink eye, and trachoma, and have been associated, but without actual proof, with the transmission of anthrax, gangrene, pyogenic skin infections, erysipelas, tuberculosis, leprosy, the exanthemata like smallpox, measles, and scarlet fever, and certain parasitic worms. The biting stable fly has been associated with the experimental transmission of poliomyelitis to monkeys, and it is now well known that the Glossina flies transmit nagana to horses and cattle and the fatal African sleeping sickness to man.

The control of Musca domestica. — The control of the common house fly may be undertaken in a variety of ways, only some of which are basically effective. Domestic relief can be obtained by effective screening, "swatting," the use of sticky fly paper, fly traps, poisons, fumigants, and sprays, but real control is achieved only by eliminating fly breeding places and by the use of certain anti-larval procedures. Campaigns against the adult fly can be only palliative at best, but measures that control reproduction are effective almost immediately. Therefore, a knowledge of the habits and life cycle of the fly is essential if satisfactory results are to be achieved.

Screening is highly desirable for the sake of personal comfort. All screens effective against the mosquito will be suitable against the fly. Screening should be accompanied with fly swatting as a protective measure in the home, and also with environmental cleanliness. The absence on the premises of organic refuse is essential if a local fly nuisance is to be avoided. Similarly the elimination of open privies, either by making them fly tight or by using sewers, is of importance in the control of flies and in minimizing their danger.

Fly traps are of use in dairies, barns, sanatoria, and other

places where flies may abound and serve to transmit infection. Their use is only palliative, however, unless they are employed at the beginning of the fly breeding season and are successful in catching the female flies before the eggs are laid. Fly traps may be made in a variety of ways, but the top should be made of screening material, and the sides are sometimes similarly constructed. The floor is made of wood or other solid material, through which a cone, made of screening material, passes upward into the trap. The apex of the cone is open, the opening, 0.25 to 0.5 inch, being large enough to permit the flies to pass through into the trap. As flies are attracted toward the light, those that leave the bait travel up the side of the cone, and pass through the opening into the trap. Theoretically, they ought to be able to make their way out again, but actually they do not. When the trap is reasonably filled, the flies must be destroyed and removed, and the trap cleaned before being used again. Sugar and water, in the ratio of 1 to 3, may be employed as suitable bait, or bread kept moistened with milk and renewed at daily intervals. Decomposing meat or fish heads or other foul-smelling, decomposing organic matter should not be employed. The house fly is not greatly attracted by such bait, but other flies normally not seen in the vicinity of the home, are attracted in large numbers.

The use of sticky fly paper and poisons are of value in controlling a local nuisance. The poison employed should not endanger the lives of human beings. One highly recommended and frequently used is formalin. A teaspoonful is added to a pint of sweetened water or of dilute milk. This is spread in shallow dishes away from the reach of children and renewed as the occasion demands.

Flies may be destroyed in a closed, sealed room by the use of fumigants such as sulphur dioxide. They may be stupefied, however, by burning or introducing pyrethrum powder into the air, or by using the effective commercial sprays now commonly sold for the purpose of insect destruction. These have been used with great success in eliminating flies in a certified milk dairy farm near Boston.* Most commercial sprays are composed of light

* The cows at these barns are kept scrupulously clean, and manure is not stored on the premises for more than 12 hours The spray is applied with doors and windows closed, after which the stupefied flies are swept up and destroyed. Milking is performed with the windows open but flies were not observed.

oil or water white kerosene combined with carbon tetrachloride to prevent fire hazards. A mixture of 2 parts of carbon tetrachloride and 98 parts of kerosene may be employed. Some commercial sprays contain pyrethrum powder dissolved in kerosene. A satisfactory pyrethrum solution may be prepared by dissolving 0.5 pound of the powder in one gallon of kerosene. Pyrethrum is also known as Bubach or Persian insect powder. It is the powdered flower of the Chrysanthemum roseum and Chrysanthemum carneum.

Fly control by prevention. — The most effective method of combating flies is by eliminating their breeding places. Since flies breed preferably in horse manure, the problem demands the daily removal of this material to suitable pits or to the fields. Doubtless the introduction of the motor vehicle and the virtual elimination of the horse from large communities, has done more to control the fly nuisance in cities than any other single factor. Similarly, in the small villages and on the farm, horses have been replaced to some extent by motorized equipment. Nevertheless, cows and horses, hogs and chickens, cannot be eliminated in these rural or semi-rural places and other preventive practices must be employed. Of these, the removal of manure, as indicated above, helps to diminish the possibility of fly breeding and yet conserve its fertilizer value. Its accumulation in large piles, as was formerly common, should be avoided.

If manure has to be stored on the premises for more than a few days it should be placed in properly constructed pits or bins which can be kept dark within. The bin should be provided with a tight-fitting cover and through it should rise a satisfactory fly trap. Flies that hatch out while the manure is being stored should find their way into this trap. The floor of the bin should be made of cement or concrete, and above it should be a false bottom on which the manure rests. The floor should be underdrained. Provision should be made too for keeping it clean and for adding water to it to a depth of at least 0.5 inch after the bin has been emptied. Fly larvae or maggots migrate away from the surface of the manure and toward the bottom. This is favored by the addition of small amounts of water to the manure from above. Eventually the maggots burrow past the false bottom and fall into the water on the floor of the bin and are drowned. A manure bin ought to be emptied and cleaned at least once a week. The

manure should be removed to farm land and spread thinly on the fields.

Another method of combating the fly nuisance is through the use of larvicides. After an exhaustive study of the problem, the U.S. Department of Agriculture came to the conclusion that powdered borax was the most efficient larvicide to use. The amount recommended is 0.62 pound for every 10 cubic feet (8 bushels) of manure. The powder is applied through a flour sifter or fine sieve, especially around the outer edges, immediately after the manure is removed, after which 2 or 3 gallons of water are sprinkled over the manure. The use of ordinary borax, however, has a deleterious effect on plant growth, and a borax-containing compound known as hellebore has been recommended in its place. A solution of 1 pound of the powder in 20 gallons of water sprinkled over the manure at the rate of 10 gallons for every 10 cubic feet (8 bushels) is effective.

Another recommended larvicide is sodium fluosilicate. It should be applied in saturated solution, 1 part sodium fluosilicate to 54 parts of water, and sprinkled over the manure every day. It is maintained that this solution is more larvicidal than borax and that it does not have any injurious effects on plants in concentrations up to 300 pounds per acre.

Requirements for effective fly control. — In order to make fly control effective in the city, there must be cooperative effort. This can be accomplished through publicity and popular education, and by means of frequent sanitary inspections, particularly during the fly breeding season. The local board of health should be the official agency responsible for the campaign and the inspections, but various voluntary welfare and health agencies in the community may render valuable aid. The local health ordinances should require also that all food stores, public eating places, and soft drink establishments should be properly screened during the fly breeding season; that pies, pastries, candy, and other confectionery products should be kept under glass; and that meats, poultry, fish, milk, and dairy products should be kept in suitable refrigerators. Fruits and vegetables should be kept off the floor in food stores, the floor should be free of organic refuse, and in warm weather revolving fans should be employed to keep existing flies from coming in contact with the foods. Sticky fly paper and dilute formalin may also be employed as aids in controlling the

fly nuisance in food stores and restaurants. Suitable precautions against flies should also be observed in milk processing establishments located within the city limits.

Stomoxys calcitrans. — This fly is known as the biting stable fly and achieved a great deal of prominence when, in 1912, Rosenau and Brues announced that, through its bite, they had succeeded in transmitting poliomyelitis from infected to non-infected monkeys. This observation was confirmed by Anderson and Frost of the U.S. Public Health Service, but later efforts to reproduce these results were unsuccessful in their hands and in others. The stable fly is therefore not regarded as a vehicle of poliomyelitis among human beings.

Stomoxys calcitrans closely resembles the ordinary house fly and is frequently found in houses. It is widely distributed throughout the world. It breeds in stable straw, manure, etc. It does not breed in human excrement and is not considered an important vector of typhoid fever. However, because it is a biting fly, it may transmit pyogenic skin infections or other skin diseases quite readily.

Its life cycle is very much longer than that of Musca domestica. Under favorable conditions it will vary between 21 and 25 days. If the conditions are not favorable, *i.e.*, if the temperature is low, the life cycle may require from 2.5 to 3.0 months or more for completion. Control of the insect is best accomplished through the elimination of its breeding places and the use of sprays in cow barns.

Glossina flies. — These flies are not found in the United States but they abound in certain areas in Africa and Arabia. They are held to be largely responsible for retarding the development of extensive areas in Africa. Certainly they have killed hundreds of thousands of humans and unrecorded numbers of domestic animals such as cattle and horses. Their elimination or effective control is mandatory if certain regions of Africa are to be opened to civilization.

The flies belonging to this group are commonly known as tsetse flies. At least two species, Glossina palpalis and Glossina tachinoides, have been shown to be capable of transmitting the Trypanosoma gambiense, the parasite of African sleeping sickness, to man. Another fly, the Glossina morsitans, transmits the parasite of nagana, the devastating disease of domesticated animals

in Africa. In this case the parasite is known as Trypanosoma brucei, discovered by David Bruce in 1894. The Glossina flies are a little larger than the house fly, but they have a totally different life cycle. Both the egg and larva are intra-uterine stages in the development of the adult fly. Both the male and female suck blood, feeding by day, and attacking a large variety of vertebrate animals for this purpose. They transmit flagellated protozoa, known as trypanosomes, to uninfected animals and these frequently produce fatal disease. In the case of nagana the parasite must undergo a process of development in Glossina at least 10 days before the insect is able to infect other animals. The control of this insect is also dependent to a large extent on the elimination of its breeding places.

CHAPTER XXI

AIR IN RELATION TO HEALTH AND COMFORT

Life is concentrated near the surface of the earth. — Man lives at the bottom of a great aërial ocean. For hundreds of centuries he has crawled about on the earth's surface, never venturing very far into the deeper layers of the earth or in the regions above it. His close affinity to the soil, his absolute dependence upon it for life and sustenance, his inability to overcome the force of gravity have held him a prisoner on the rim of this revolving planet. Unable, as a result of evolutionary processes, to survive without air, he cannot inhabit the sea for any extended length of time; unable to explore extensively the depths of the earth and survive, or to reach and endure the cold and altered atmosphere high above the earth's surface, man has had to remain content with a terrestrial existence. It is only in the recent years of his existence that he has been able, through his inventive genius, to leave his normal environment. He has been able to penetrate the earth's surface for a distance of a thousand feet, but in order to do so it has been necessary to depend on the unceasing operation of ventilating equipment to supply the precious oxygen so essential for life. The balloon and later the airplane have carried him above the earth's surface, and it is only a few years ago that Professor Auguste Piccard reached the highest point in the atmosphere ever attained by man, the so-called stratosphere, a height of ten miles above the earth's surface. To do this he used a balloon and an air-tight gondola, equipped with heating facilities, with a source of oxygen and a means of absorbing the carbon dioxide resulting from respiration. Since the earth is 93,000,000 miles away from the sun, this accomplishment, great as it is, emphasizes once more how closely human life is linked up with surface terrestrial conditions. Similarly, by means of a "bathysphere," William Beebe of the New York Zoological Society has succeeded in penetrating the ocean depths to over half a mile.

Man's relationship to oxygen in the air. — The secret that links man so intimately to the earth is not difficult to find, for by nature

he is equipped to survive under rather restricted atmospheric conditions. The outdoor air contains 20.93 per cent oxygen by volume, and oxygen is indispensable for human life. Even in the innermost recesses of the lungs, the alveolar spaces, the atmosphere contains from 14 to 16 per cent oxygen, an amount comparable to that found on Pike's Peak, at an elevation of 13,000 feet, where the oxygen content of the air at ordinary atmospheric pressure is about 13 per cent. Despite this marked diminution in oxygen at high altitudes, people can and have become acclimated to life at such elevations, and are able to live an active, normal existence without showing any ill effects. Some of the members of the various Mount Everest expeditions have thus been able to reach a height of 28,000 feet without the aid of oxygen apparatus.

However, when an individual is transferred rapidly from an atmosphere containing 20.93 per cent oxygen to one containing the equivalent of 12 to 14 per cent or less, the symptoms of mountain sickness make their appearance. These are excessive breathing, blueness of the lips and face, increase in the pulse rate, loss of mental acuteness, loss of appetite, nausea, vomiting, headache, intestinal disturbances, and fainting. If the oxygen content is diminished to an equivalent of 5 per cent, cyanosis becomes marked and consciousness is lost rapidly. If the air is deoxygenated entirely, consciousness is lost within about 45 seconds, convulsions follow, and death occurs promptly. It is no wonder, therefore, that man's dependence on the oxygen supply of the atmosphere colored his views on the essentials of good ventilation for a long time.

Man's great interest in atmospheric comfort. — The need of a constant source of oxygen is not the only demand the human organism makes upon the atmosphere. The atmosphere must also serve as an important aid in the regulation of the body temperature. In fact, the oxygen content of the atmosphere is usually taken for granted; but whether or not the atmosphere is conducive to comfort and to a sense of well-being is a subject which has commanded the interest and attention of man for a long time. Indeed it is a subject of expanding interest at the moment for not only is the conditioning of the atmosphere mandatory today for schools, auditoria, and industrial establishments, but air conditioned offices, banks, hospitals, and trains are increasing in number and air conditioning of homes in summer as well as in winter is

expected to be as universal in the next generation as electric refrigeration is in this. Certainly the mass movement of humans during the summer months from the congested cities to the cooler, freer atmosphere of the seashore, open country, and mountains, is additional evidence of the importance which is placed on atmospheric comfort.

Man's relationship to temperature, relative humidity, and air movement. — The temperature of the air depends on solar and terrestrial radiation to a large extent. The air absorbs enormous quantities of heat from the sun as well as the heat radiated from the earth. Anyone who has experienced a total eclipse of the sun will recall the sudden cooling of the atmosphere. The atmosphere acts as an aërial blanket around the earth protecting it from the extreme heat of the sun by day, and warming it by night. But the capacity of the air to absorb and retain heat is dependent on the amount of water vapor, or humidity, it contains. Water vapor is opaque to heat rays but it serves as a great reservoir of latent heat. When water evaporates into the atmosphere it carries with it enormous quantities of latent heat, and when it condenses this heat is actually given off.

That the temperature of the air has a profound effect on human health and comfort is almost a universal experience. The inability of infants to endure the heat of summer, especially in combination with other deleterious factors such as overfeeding or a poor milk supply, is generally recognized. Deaths from heat stroke also occur during the summer months primarily and are largely due to combinations of temperature and humidity. Ellsworth Huntington concludes from a study of the death rates in the United States and Europe that human health is best when the average temperature is about 64° F., or when it is approximately 70° F. at noon and 55° F. at night; in other words, when windows are open and artificial heat in the home is not required.

But the ability of man to withstand wide variations in temperature is noteworthy, an achievement made possible by his remarkable powers of adaptation. Although the temperature of the body in a state of health remains constant at approximately 98.6° F., men in foundries are often exposed for brief periods to temperatures as high as 250° F. or higher, while on polar expeditions temperatures as low as −75° F. have been experienced. Thus there is a variation of at least 325° F. to which the body of man

may be exposed. At higher temperatures than the body, the amount of clothing worn is exceedingly limited. Perspiration then occurs freely, and the evaporation that takes place produces the necessary cooling effect. The water loss through the skin under these conditions is enormous, often several gallons, and kidney function becomes greatly diminished. It is necessary to replenish this water loss in order to maintain bodily health. Since perspiration causes the body to lose salt as well as water, this must also be replaced if pain and suffering are to be avoided. On the other hand, when the temperature of the surrounding air is low, the amount of clothing worn may be greatly increased, and in extreme weather woolens become essential to retain the heat of the body. The purpose of the clothing is primarily to keep intact, or regulate the exchange of the warm layer of air that surrounds the body. This aërial blanket must be conserved during cold weather and must be dissipated frequently during hot weather if health and comfort are to be maintained. In this exchange, humidity enters as an important and complicating factor. While hot dry air may be borne with reasonable comfort, hot, humid air prevents the body from giving up its heat readily, the heat regulating mechanism is disturbed, and the body temperature rises. In extreme cases heat stroke may result. Similarly, cold, dry air may be endured quite readily if the body is reasonably protected, but cold, moist air robs the body of its heat more readily, and comfort is more difficult.

Both of these factors are complicated still further by a third, namely air movement. All are familiar with the comfort and revivifying effect of an electric fan on a hot, humid summer day, or, on the other hand, with the discomfort and chilling effect of a piercing, northwest wind during the winter. When the atmosphere is hot and humid, and the air is in motion, the aërial blanket surrounding the body, or part of it, is being removed constantly. As a result, the body gives up its heat more readily and comfort is obtained. In winter, however, the body must retain its warm and moist aërial blanket in order to conserve its heat, and strong draughts or pronounced air movements then produce a chilling effect which results in discomfort and eventually in lowering the vital resistance.

The temperature, relative humidity, and velocity of the air, therefore, have a significant effect on human health and comfort,

but the importance of the proper adjustment of these three atmospheric factors in ventilation is a discovery of comparatively recent origin. We know today that air of a suitable temperature, relative humidity, and velocity of flow is essential for comfort, for good health, for stimulating the appetite, for good metabolism and for industrial and mental efficiency. The atmospheric factors influencing comfort and health were formerly ascribed to other agencies, and vestiges of these older views are still current in popular tradition. It is desirable, therefore, to review briefly the earlier theories concerning satisfactory ventilation, and to give the experimental evidence that led to their abandonment and the adoption of the present point of view. To do this it is necessary and logical to study first the chemical composition of the atmosphere and of respired air; but before doing so, two famous cases of poor ventilation and the resulting havoc should be described for they serve once more to illustrate the utter dependence of man on the surrounding atmosphere.

The Black Hole of Calcutta. — Professor F. S. Lee of Columbia University describes the famous tragedy of the Black Hole of Calcutta as follows:

"On one of the hottest of the hot nights of British India, a little more than one hundred and fifty years ago, Siraj-Addaula, a youthful, merciless ruler of Bengal, caused to be confined within a small cell in Fort William, 146 Englishmen, whom he had that day captured in a siege of the city of Calcutta. The room was large enough to house comfortably but two persons. Its heavy door was bolted; its walls were pierced by two windows barred with iron, through which little air could enter. The night slowly passed away, and with the advent of the morning death had come to all but a score of the luckless company. A survivor has left an account of horrible happenings within the dungeon, of terrible strugglings of a steaming mass of sentient human bodies for the insufficient air. Within a few minutes after entrance every man was bathed in a wet perspiration and was searching for ways of escape from the stifling heat. Clothing was soon stripped off. Breathing became difficult. There were vain onslaughts on the windows; there were vain efforts to force the door. Thirst grew intolerable and there were ravings for the water which the guards passed in between the bars, not from feelings of mercy, but only to witness in ghoulish glee the added struggles for impossible relief. Ungovernable con-

fusion and turmoil and riot soon reigned. Men became delirious. If any found sufficient room to fall to the floor, it was only to fall to their death, for they were trampled upon, crushed, and buried beneath the fiercely desperate wave of frenzied humanity above. The strongest sought death, some by praying for the hastening of the end; some by heaping insults upon the guards to try to induce them to shoot. But all efforts for relief were in vain, until at last bodily and mental agony was followed by stupor. This tragedy of the Black Hole of Calcutta will ever remain as the most drastic demonstration in human history of the bondage of man to the air that surrounds him."

The tragedy of the *S.S. Londonderry*. — The second famous tragedy resulting from the effects of overcrowding with little or no ventilation occurred on board the *Londonderry*, which left Sligo for Liverpool in December, 1848, with two hundred passengers. The experience is described by G. H. Lewes in *The Physiology of Common Life*, published in 1860. "Stormy weather came on, and the captain ordered everyone to go below. The cabin for the steerage passengers was only 18 feet long, 11 feet wide, and 7 feet high. Into this small place the passengers were crowded; they would only have suffered inconvenience, if the hatches had been left open; but the captain ordered these to be closed, and — for some reason not explained — he ordered a tarpaulin to be thrown over the entrance to the cabin, and fastened down. The wretched passengers were now compelled to breathe over and over again the same air. This soon became intolerable. Then occurred a horrible scene of frenzy and violence, amid the groans of the expiring and the curses of the more robust; this was stopped only by one of the men contriving to force his way on deck, and to alarm the mate, who was called to a fearful spectacle: seventy-two were already dead, and many were dying; their bodies were convulsed, the blood starting from their eyes, nostrils, and ears."

Composition of the atmosphere. — Since air has such a profound effect on human life, comfort, and health, it is only natural that the secret of its powers should be sought in the chemical, physical, and biological composition of the atmosphere. Chemically, air, remarkably uniform the world over, is composed of a variety of gases. Its composition is best illustrated in the following table.

TABLE 16

APPROXIMATE COMPOSITION OF THE OUTDOOR ATMOSPHERE AT 0° C. AND 760 MM. PRESSURE

Gas	Per Cent	
	By Volume	By Weight
Nitrogen	78.09	76.8
Oxygen	20.94	23.2
Argon	0.94	
Carbon dioxide	0.03	
Helium, krypton, neon, xenon, hydrogen, hydrogen peroxide, ammonia, ozone	traces	

The oxygen deficiency theory of ventilation. — Oxygen, as is universally known, is essential for animal life. When a mouse is placed under a bell jar it dies eventually of oxygen starvation. Therefore, it is not surprising that one of the earliest theories explaining poor ventilation was associated with a deficiency of oxygen in the atmosphere. But the oxygen content even of poorly ventilated rooms rarely falls below 20 per cent by volume, an amount more than adequate to sustain life. Furthermore, the equivalent amount of oxygen in the air at high altitudes is equal to only 13 per cent, and yet life and normal activity are possible without the aid of oxygen tanks after the individual has become acclimatized. In ordinary respiration the oxygen content of the alveolar air in the lungs is reduced to 16 per cent or less, and yet this is a perfectly normal condition. Likewise, in some mines, the oxygen content of the air is purposely diminished to 17 per cent by volume, in order to minimize the danger of explosions, and yet the miners continue to live and to function normally. Furthermore, Hermans, in Germany, in 1883, kept several human beings for a few hours in an air-tight chamber where the atmosphere contained only 15 per cent oxygen and as much as 2 to 4 per cent carbon dioxide, without producing any toxic effects. In submarines the oxygen content of the atmosphere is not replenished until it falls to 16 per cent. At this concentration a lighted candle will be extinguished, but an acetylene flame continues to burn until the oxygen content of the atmosphere is diminished to 12.5 per cent. There is therefore a great factor of safety as far as the oxygen content of the air is concerned, and human life does not become endangered until it reaches 10 to 12 per cent or less. The oxygen content of *normal* air, therefore, can have no effect on human health

and comfort and is not a factor in good ventilation. Oxygen and carbon dioxide are constantly liberated into the atmosphere through plant respiration, while carbon dioxide is being assimilated.

The inert gases and ventilation. — As previously noted, the atmosphere is composed to a large extent of nitrogen, an inert gas. It is estimated that there are approximately four million billion tons of nitrogen in the atmosphere. While a very small fraction of this nitrogen is utilized through the agency of specific bacteria to replenish the nitrogen content of the soil, nitrogen *per se* does not play any part in respiration or satisfactory ventilation. The same may be said of the other inert gases, argon, helium, krypton, neon, and xenon. Even ozone, as far as present evidence indicates, does not play any part in producing improved atmospheric conditions.

Carbon dioxide and ventilation. — The part played by carbon dioxide in the atmosphere has been subject to much speculation, research, and discussion. Carbon dioxide is a product of both animal and plant respiration, and it is not surprising, therefore, that in the early days of science this waste product should have been considered the responsible element in vitiated air. An adult in normal health and engaged in quiet work breathes from 17 to 18 times per minute, and with each respiration about 500 cc. of air pass in and out of his lungs. The nitrogen content of respired air is unchanged, but the oxygen content is diminished from 20.94 per cent to approximately 16 per cent, and the carbon dioxide content is increased from 0.03 per cent to 5.0 per cent. Lavoisier, in 1777, was probably the first to associate the carbon dioxide content of the atmosphere with discomfort, and this view was supported and "substantiated experimentally" by such prominent scientists of the nineteenth century as Claude Bernard (1857) and Paul Bert. It was Professor Max von Pettenkofer of Germany, who in 1862 to 1863, first cast doubt on the validity of the carbon dioxide theory of ventilation. He showed that the carbon dioxide content of vitiated air in poorly ventilated rooms was far below the level at which harmful effects were observed in laboratory experiments, and he concluded that the increase in carbon dioxide was no more responsible for the unfavorable symptoms produced by bad air than the diminution of the oxygen content of the air.

This view is supported by ample and incontrovertible evidence

today, but it took over 50 years for this idea to become established in the popular mind, and all this time, the carbon dioxide content of air was taken as the index of vitiated air, and was used as the yardstick for efficiency of ventilation. Today, we know that under normal conditions of human occupancy, the carbon dioxide content of a living room, schoolroom, assembly hall, or workshop, practically never reaches a concentration injurious to man. Carbon dioxide in itself is not irritating or poisonous and is taken into the body in large volumes in bottled beverages, beer, and in other ways. Although the amount of carbon dioxide in expired air is 5 per cent by volume, the carbon dioxide content of outdoor air is only 0.03 per cent, and indoor air, even if badly vitiated, rarely is in excess of 0.5 per cent. Since unfavorable symptoms due to carbon dioxide do not develop until its concentration in the air reaches 7 to 8 per cent, it is apparent that it cannot be regarded as significant under ordinary conditions of human habitation.

Definite physiological evidence is now available to support this view. Experimentally it has been found that when the carbon dioxide content of the air is increased to 2 per cent, the only effect is an automatic increase in the depth of breathing. It is estimated this increase is equal to 50 per cent. As the concentration of carbon dioxide is increased up to 5 per cent, there is no further effect other than a continued increase in the depth of breathing. At 5 per cent, there is distinct panting, and at 7 per cent dyspnea becomes distressing, even when the patient is at rest. With the carbon dioxide concentration at 10 to 11 per cent, the patient experiences headache, nausea, and chilliness, and above this concentration man soon becomes unconscious, and suffocation occurs when the carbon dioxide content of the atmosphere reaches 30 per cent.

Toxic organic substances in expired air and ventilation. — Since a deficiency of oxygen and an increase in the carbon dioxide content of indoor air could not be held responsible for poor ventilation and its unfavorable physiological effects, it was only natural that some other theory be developed. This was not lacking, for between 1880 and 1890 Brown-Sequard of France propounded and defended the theory that the effects of poor ventilation were due to the presence of toxic organic substances in respired air. Brown-Sequard, collaborating with d'Arsonval, showed that when animals are placed in a series of cages, and each animal is successively re-

quired to breathe the vitiated air of the preceding cages, then the animals last in the chain succumbed, and only the first, or possibly the first and second animals in the series, survived. However, if the vitiated air from each cage was first passed through sulphuric acid then all the animals survived and no unfavorable symptoms occurred.

From these and other experiments it was concluded that specific toxic organic substances are given off in respired air which are responsible for poor ventilation and its accompanying unfavorable physiological effects. Other investigators repeated Brown-Sequard's experiments with negative results, and animals kept under experimental conditions showed perfectly normal growth curves and no increased susceptibility to disease resulting from infected food, even though they were compelled to live in an atmosphere containing sewer gas. Similarly, guinea pigs exposed to an atmosphere containing decomposing fecal matter showed no ill effects other than a slight loss of appetite. It has also been found experimentally that breathing vitiated air impairs the appetite of human subjects, while breathing fresh air exerts a stimulating effect. Obviously, therefore, no great weight can be placed on the point of view that poor ventilation is the result of toxic organic substances given off in the form of body odors from the skin, mouth, or clothing, although the undesirability of such conditions is apparent.

Dangers of atmospheric dusts and bacteria. — Having presented evidence to show that the effects of poor ventilation are not due to normal alterations in the chemical composition of indoor air or to the presence of specific chemical poisons or toxins resulting from body odors, it is now necessary to inquire into the effects of the biological and physical components of the atmosphere. Of the various biological components, doubtless the most numerous are the microörganisms — bacteria, yeasts, molds, etc. — and of these the bacteria are the most significant from the standpoint of health and disease. But the number of bacteria per unit volume of air varies enormously, depending for the most part on the number of dust particles present and especially on the amount of soil-dust from the surface of the earth, and on the extent of human and animal contamination present. Air at high elevations such as the top of a mountain, or air at sea, is comparatively low in bacterial content. On the other hand, air at low elevations on a windy day, or at crowded street intersections, or in open rural regions where crops are grown, shows comparatively large numbers of bacteria. Similarly

indoor air, contaminated with the dust resulting from dry sweeping may show large numbers of bacteria, and some of the organisms may be pathogens such as staphylococci, streptococci, pneumococci, tubercle bacilli, and spore formers. But the danger of aërial infection is slight except through droplet infection, and the vegetative bacteria tend to die out because of dryness, lack of proper food, and the germicidal effects of sunlight. Furthermore, droplet infection is a form of contact infection and cannot be regarded as simple aërial infection. Under special circumstances, where an unusual amount of infected dust is liberated into the atmosphere or where an individual is required to work in a dusty atmosphere, a real hazard may exist, but these are not the conditions that normally obtain in the home, office, schoolroom, or laboratory, so that they are, in reality, of minor significance. In industry, the law requires occupational dust hazards to be eliminated, or if this is difficult or impossible, the individual is protected by the use of respirators or in other ways. But the amount of dust *normally* present in the air does not represent a nuisance or menace to health, and is not a factor in determining the discomfort associated with poor ventilation.

Ventilation and physical factors. Current theory. — If we turn now to the physical components of the atmosphere and examine their influence on comfort and discomfort, a very striking correlation is found. In fact, the prevailing theory concerning good ventilation is based on the experimental findings, now corroborated in Germany, England, and the United States, that it is the physical quality of the air which determines comfort or lack of it. The problem of ventilation therefore is physical rather than chemical, and cutaneous rather than respiratory. Among the physical factors that must be considered are temperature, relative humidity, air movement, and possibly ionization. Furthermore, these factors must be considered simultaneously, and not separately, if the comfort of the individual is to be the criterion. The whole subject is greatly complicated by the remarkable adaptability of the human organism, by the psychological element, by the amount and character of clothing which the individual wears, by his nutrition and robustness, and doubtless by numerous other factors, so that individual reactions are not always the best criteria of good or poor ventilation, although they are the most reliable we now possess. Even if suitable objective criteria of good ventilation, some of which exist already, are used, there will always be the subjective

reaction of the individual, which in the last analysis must be the deciding factor.

Air conditioning, an important growing industry. — A tremendous popular interest has of late been developed in the field of air conditioning. Industries which depend for successful operation on air conditioning have been able to manufacture indoor weather conditions to meet their particular needs. By means of special engineering equipment, air of any required temperature, relative humidity, and velocity can be provided throughout the year. Thermostats regulate the temperature, humidistats, the relative humidity, and large, rotary fans control the velocity of the incoming air. Air is warmed and humidified in winter and cooled and dehumidified in summer. Offices, banks, hospitals, moving picture theaters, film factories, textile mills, candy factories, pasteurizing rooms, drying tunnels, and other places are now air-conditioned throughout the year. Even railroad trains have been air-conditioned, so that travel in such cases has been freed of the dust, dirt, heat, drafts, and general discomfort experienced in the past.

It is estimated that there are 30,000,000 homes in the United States (1933), and the problem confronting air-conditioning engineers is the development of suitable equipment for each home which shall be cheap to install and inexpensive to operate. The problem is one of economics rather than of engineering skill or knowledge. It is further complicated by the lack of provision in the past for suitable insulation of homes. The amount of air transfer through cracks, doors, windows, and even walls is enormous. It increases the cost of heating during the winter and augments the problem of cooling and dehumidification in the summer. If houses were properly insulated, the amount of heat required in winter would be greatly diminished, and it is doubtful whether air conditioning in summer would be necessary except in certain localities and during periods of extreme heat and relative humidity. Thorough insulation would also eliminate much of the nuisances due to dusts and noise.

Relative humidity. — All air contains a certain amount of water vapor, but the amount it can hold is governed by the temperature. If the moisture content of air at a given temperature is increased, the saturation point will be reached eventually. If additional water vapor is introduced, the excess above saturation will settle out in the form of dew. Or if air at a given temperature

contains a certain amount of water vapor and the temperature of the air is lowered, eventually a point will be reached where the air is saturated with moisture and dew begins to form. This temperature is known as the "dew point." The amount of water vapor in the air is often referred to as humidity, but ordinarily the term commonly employed is relative humidity and this has a slightly different meaning. Relative humidity is defined as the ratio of humidity in the air at a given temperature, to the amount of humidity which the same volume of air could hold at the same temperature if saturated, expressed in terms of per cent. Thus if the relative humidity of air at 70° F. is 50 per cent, then the amount of water vapor present is one-half of the amount which air at that temperature could hold if it were saturated.

The amount of water vapor a given volume of air can hold varies enormously with the temperature. The higher the temperature the greater the amount of water vapor air can hold. Thus the primary method of dehumidification consists of cooling or refrigerating the air. On the other hand, additional humidification is accomplished by introducing steam into the air or by allowing warm air to pass through a "water curtain" or to come in contact with a large moist area such as a sheet of canvas. The following table illustrates the amount of water vapor which air can hold at different temperatures.

TABLE 17

AMOUNT OF WATER VAPOR WHICH 1 CUBIC FOOT OF AIR CAN HOLD AT DIFFERENT TEMPERATURES

Temperature Degrees F.	Water Vapor in Grains
0	0.5
10	1.1
20	1.5
30	2.1
32	2.1
40	3.0
50	4.2
60	5.8
68	7.5
70	7.9
80	10.0
90	14.3
98	18.7
100	19.1

From the preceding table it is apparent that air taken into a home at 0° F. and 100 per cent relative humidity, and subsequently heated to 70° F. without the addition of more water vapor, will exhibit a relative humidity of only 6 or 7 per cent at the higher temperature, since air at 70° F. can hold sixteen times as much water vapor as air at 0° F. Even air at 32° F. with a relative humidity of 100 per cent, if warmed to 70° F. without additional humidification, will have a relative humidity at the higher temperature of only 25 per cent approximately. Since air at 70° F. ought to contain from 30 to 50 per cent relative humidity, these two instances illustrate the difficulty and seriousness of the problem of properly humidifying the indoor atmosphere during the colder months of the year. No wonder doors, floors, and furniture in American homes become excessively dry during the winter months when the temperature is maintained at 70° F. or higher, and humidification is rarely practised. The mucous membranes of the nose are likewise robbed of their moisture, the skin becomes dry and cool, and since comfort depends on the cutaneous reaction, the air must be heated above 70° F. This leads to overheating and to the perpetuation of a vicious circle. Heating indoor air must always be regarded therefore not only as a problem of heat transfer but likewise one of humidification.

Although relative humidity may be determined in various ways, the most convenient and simplest method is by means of the sling psychrometer. This consists of two accurate mercury thermometers, attached to a metal case and so arranged that the whole apparatus can be whirled through the air. One thermometer is used to obtain a reading of the dry bulb temperature and the other, the wet bulb temperature. The bulbs of both thermometers extend beyond the metal case, the wet bulb thermometer extending somewhat further. The latter also has a close fitting sleeve of muslin or silk which covers the mercury bulb completely. In order to determine the relative humidity, the wet bulb thermometer with the muslin cap in position is immersed in distilled water, and the psychrometer is then whirled through the air for one minute. Care should be taken to avoid a position in direct sunlight or in a breeze. After whirling, the wet bulb thermometer is quickly read, and the psychrometer is whirled once more for an additional 15 seconds, and the wet

bulb reading observed once more. When two successive wet bulb readings coincide, the temperature is recorded, and the reading of the dry bulb thermometer is then observed. Unless the air has a relative humidity of 100 per cent, there will be a difference between the readings of the wet and dry bulb thermometers, for in swinging the wet bulb thermometer through the air, moisture evaporates from the muslin sleeve, and a cooling effect is produced. By referring to suitable tables the difference between the readings of the wet and dry bulb thermometers can be translated into terms of relative humidity for the particular dry bulb temperature observed. For very exact determinations of relative humidity allowance must also be made for the prevailing atmospheric pressure.

As a result of numerous observations made on human beings, the temperature and relative humidity limits of a "comfort zone" has been determined. The maximum temperature of this zone is 70° F. and the minimum relative humidity, 30 per cent. The minimum temperature varies between 55° and 60° F. and the maximum relative humidity for this temperature is 55 per cent. The effect of relative humidity on comfort seems to be least when the dry bulb temperature is around 68° F., but if the temperature is altered even a few degrees on either side, then the relative humidity begins to exert more significant effects. The maximum wet bulb temperature that can be endured with comfort is between 68° and 70° F. Above that, discomfort and even danger may be experienced. For this reason, humid days even of moderate temperature are exceedingly disagreeable unless the clothing can be removed and physical activity reduced to a minimum. Heat stroke therefore may occur even at comparatively moderate temperatures, *i.e.*, between 80° and 90° F. if the relative humidity is near 100 per cent, depending on the air movement, the amount of clothing, and the degree of physical activity. Physical comfort and health can be achieved only if the heat loss from the body is carefully regulated, and this depends on a properly adjusted atmospheric environment.

Establishment of the thermal theory of ventilation. — Perhaps the first to state definitely that temperature and relative humidity represented the keystone to the problem of ventilation was J. T. F. Hermans of Germany. In 1883 Hermans demonstrated that he could not obtain any specific toxic organic substance from the

air of a closed chamber vitiated by human beings, and that an atmosphere containing only 15 per cent oxygen and as much as 2 to 4 per cent of carbon dioxide was not toxic. He also observed that it was a combination of temperature and relative humidity which determined physical comfort and body temperature. It was not, however, until 1905 that the thermal theory of ventilation was put on a firm, scientific foundation. This was accomplished through the work of Professor Flügge and his pupils, Heymann, Paul, and Ercklentz at the Breslau Institute of Hygiene. Their findings were soon corroborated and extended by Haldane, Pembroke, Boycott, and Hill of England, and subsequently, too, by the New York State Commission on Ventilation under the active direction of Winslow and Palmer.

Besides demonstrating once more that the chemical impurities of indoor air had no effect on physical comfort, the Breslau investigators showed that if a human subject were placed in a closed cabinet having a capacity of 3 cubic meters, the temperature raised to 75° F., the relative humidity to 89 per cent, and the carbon dioxide content of the air to 1.2 per cent, during a period of confinement of 4¾ hours, the patient became very uncomfortable. Furthermore, individuals outside the cabinet but breathing the same air through a mouthpiece experienced no discomfort; but when one of their number entered the chamber, discomfort was experienced immediately. Similarly, an individual inside the chamber, with the temperature adjusted to 86° F., the relative humidity to 87 per cent, and the carbon dioxide to 1.1 per cent, experienced no relief even though he was permitted to breathe the pure outside air. However, when the temperature of the air in the chamber was diminished to 62.6° F., even though the carbon dioxide increased to 1.6 per cent, all symptoms of discomfort disappeared immediately. A similar effect was observed when the individual in the experimental chamber was allowed to turn on a revolving fan. The cooling effect produced by the circulating air was sufficient to eliminate the feeling of discomfort even though the temperature, relative humidity, and carbon dioxide content remained the same. Here was conclusive evidence that the ill effects of poor ventilation were due to physical rather than chemical factors, and were cutaneous in character and not respiratory.

The cutaneous effects of moving air vary with the temperature

and relative humidity. The movement of warm air is less perceptible than the movement of cool air. When air is at 55° to 60° F. the various cutaneous effects produced by different velocities as measured by means of an anemometer are as follows:

Rate of Air Movement		Effect
Feet per Second	Miles per Hour	
1.5	1.0	Imperceptible
2.5	1.7	Barely perceptible
3.0	2.0	Perceptible
3.5	2.3	Draft

Requirements for suitable indoor atmospheric conditions. — Having discussed the effects of the chemical, physical, and biological components of the atmosphere, the requirements of suitable air conditions may now be summarized. Individual idiosyncrasies may require slight modifications in the standards suggested. Satisfactory results will generally obtain, however, if the temperature of the air varies between 65° and 68° F., the relative humidity between 30 and 50 per cent, if the wet bulb temperature is less than 70° F., if the air movement is between 1.7 and 2.0 miles per hour (1.8 to 3 feet per second), and if drafts are avoided. Furthermore the carbon dioxide content of the air should be less than 6 parts in 10,000; the air should be free of excessive dusts, bacteria, objectionable gases, and offensive odors; and it should be replaced about two or three times per hour. The requirement that 30 cubic feet of air per minute should be supplied to every pupil in a schoolroom — often found in heating and ventilating codes — has no basis of fact.

The kata-thermometer. — Since the ordinary thermometer measures only the degree of heat and not its quantity, and since human comfort in relation to atmospheric conditions depends on temperature not only, but also on the relative humidity and air movement, an effort has been made to devise an instrument which would measure the cooling powers of the air when all three factors — temperature, relative humidity, and air movement — are taken into account simultaneously. This was accomplished by Hill when he introduced the kata-thermometer. Although it is superior to the ordinary thermometer, it still falls short as an objective measure of the cooling power of air in comparison with the

subjective reaction of the human body. For this reason its readings must be interpreted with care and in the light of human experience.

In its present form, the kata-thermometer which according to Hill should have an alcohol column instead of a mercury column, is graduated at 100° F. and at 95° F. It may be a dry bulb thermometer, covered or uncovered, and if covered, the material may simulate any of the apparel of man in composition, texture, and color. It may also be used as a wet bulb thermometer. By means of a stop watch, the time, in seconds, required for the thermometer to fall from 100° F. to 95° F. is carefully determined. At least four to six readings are taken, and the first one, which is always inaccurate, is omitted from the calculations. The time required is a measure of the cooling effect of the atmosphere. By suitable computations it is possible to use this information to determine the rate of cooling at body temperature in terms of millicalories per square centimeter per second. The dry kata-thermometer gives the rate of cooling effected by radiation and convection, while the wet kata-thermometer includes evaporation as well.

Washing and recirculating used air. — Because of the expense entailed in heating outdoor air to approximately 70° F. for indoor use in winter, and also because such heated air is excessively dry, the suggestion has been made that indoor air might be "laundered" and used over again. This can be done without injury or discomfort to man if the system of washing and recirculation is properly supervised. The used air is washed by passing it through a shower or water spray of sufficient depth to remove most of the dust and microbes and to increase the relative humidity. The air so washed is then warmed to the required temperature and introduced through ducts into the various rooms served. Depending on the efficiency of the treatment, it is estimated that from 37 to 88 per cent of the bacteria and from 27 to 87 per cent of the dust particles are removed by washing air. In one demonstration a saving of 40 per cent on the cost of heating was made when recirculation was employed. Washing used air failed to remove body odors, and this deficiency may be of significance under certain conditions. Ordinarily, however, indoor air is being constantly diluted with fresh outdoor air, through the leaks in doors, windows, and even through walls, so that there is little likelihood that any chemical poison in the used air would become sufficiently concentrated to be harmful.

Washing air also fails to remove the carbon dioxide present but its content may be somewhat reduced. In domestic heating recirculation of air without washing is the common practice today, and is regarded as scientifically sound and economically desirable.

Mechanical ventilation. — Mechanical ventilation is invariably associated with a heating system and so the two must be considered simultaneously. Mechanical systems of ventilation are of two types. Either the plenum or vacuum systems may be used alone or both may be combined. Ordinarily the plenum system is used separately or it is combined with the vacuum plan, but the latter is never used alone. In the plenum system the air is taken into the building through a special air intake, warmed by passing over heated coils, after which it is picked up by a large revolving fan and delivered through special ducts into each room. Sometimes the air is washed and humidified, more frequently it is not. Sometimes the air intake is located high above the ground where the air is freer of dust particles and bacteria, but only too often the air intake is near the ground. After the air is introduced into the room, provision is made to remove it through a special exhaust duct usually located in the same wall but at a different level. The exhaust duct discharges out of doors and is often protected against wind and rain by means of a movable cowl. Circulation is facilitated by warming the air in the exhaust duct or by means of a suction fan located near the outlet end.

In some buildings, notably schools, ventilation is accomplished by thermal circulation instead of by the plenum system. The plan is essentially similar to that described in the preceding paragraph except that a fan is not employed. The air is warmed in the basement and thus becoming lighter, rises, and is distributed to the rooms through special ducts. This method of ventilation is simultaneously a method of heating and is known as the indirect method of heating. Direct heating occurs when steam or hot water is circulated through pipes or radiators in each room, the air of the room being warmed directly by radiation. In many schools a combination of direct and indirect heating is employed. It has been suggested recently that a more effective method of heating homes, schoolrooms, offices, and other human habitations, would be to heat the walls and not the air in each room. In this way the heat of the body will not be given up constantly to warm the colder walls, and the individual would feel comfortable in an

atmosphere considerably below 68° or 70° F. This method of heating is still in the experimental stage, but it has interesting possibilities.

Where mechanical ventilation is employed, successful operation depends to some extent on keeping the doors and windows closed. This is rarely achieved in practice. In hundreds of inspections of schoolroom conditions made in different parts of the United States, it was unusual to find a classroom with satisfactory air conditions where artificial ventilation was employed. Usually the air was too hot and dry and sometimes complaints of serious drafts were heard. Where mechanical ventilation is employed, provision should always be made for humidifying the air. The problem of obtaining adequate humidification is exceedingly difficult. It is easier of achievement when indirect rather than direct heating is employed. The amount of water that must be transformed into water vapor to properly humidify the average American dwelling or school is surprisingly large. It has been estimated that in a house containing 17,000 cubic feet of air space, approximately an eight- or nine-room house, it would be necessary to evaporate 15 gallons of water per day in order to obtain a relative humidity of 40 per cent at 70° F. when there is only one change of air per hour and the air supplied for heating already contains 20 per cent relative humidity. Since outdoor air at 0° F. and a relative humidity of 50 per cent, if heated to 70° F. without the addition of water vapor, would have a relative humidity of only 3 per cent, and such air is drier than any desert air known to man, the problem and importance of adequate humidification may be more fully appreciated.

Natural ventilation. — Natural ventilation is accomplished through the use of open doors and windows, through the ingress of outdoor air through cracks, crevices, and fireplaces, and by the surprisingly large amount of air that passes through the walls of buildings. The extent of air intake through walls is dependent on many factors, such as the materials used in construction, the presence or absence of double walls, the coverings on the walls, and the amount and character of insulation. For residences, natural ventilation is the accepted practice, and except for short intervals of hot and humid weather during the summer, and the reverse in winter, this method is usually satisfactory. Ordinarily the number of people per family is not large enough to interfere

with the successful operation of natural ventilation in the home. In small apartments, hotels, and office buildings, with limited window space and limited access to fresh air and prevailing winds, natural ventilation may not prove sufficient. In single, detached residences and in other houses used as dwellings, much can be done to keep out the heat of summer on the southerly and westerly sides during the daytime by keeping the windows closed and the shades drawn. Sufficient natural ventilation presents no problem in the home during the colder months of the year. The problem then is one of keeping excess cold air out and the intelligent use of open windows to suit the prevailing outdoor conditions.

There has been considerable discussion concerning the relative merits of mechanical *versus* natural ventilation in schools. The New York Commission on Ventilation found that children in classrooms provided with natural ventilation experienced less respiratory disease than other children in the same schools who were in rooms provided with mechanical ventilation. As mentioned above, numerous inspections of classroom conditions showed that natural ventilation invariably provided better atmospheric conditions than mechanical ventilation. The New York Commission on Ventilation recommended that classrooms be ventilated through the use of open windows; that the windows be provided with air deflectors to avoid direct drafts; that heat be supplied through radiators located directly under each window and extending across its entire width; and that an exhaust duct be provided in the wall opposite the windows, opening near the ceiling and discharging out of doors. The exhaust duct may be warmed to facilitate circulation and its opening to the outside air should be protected by a movable cowl.

Ventilation requires intelligent supervision. — It is doubtful whether any system of ventilation, natural or mechanical, can operate satisfactorily without the aid of intelligent supervision. Windows opened too wide in inclement weather will produce disastrous results. Similarly, a mechanical system operated carelessly and without regard to the essentials of atmospheric comfort, even if equipped with supposedly fool-proof controls, will yield intolerable conditions. Schools have been heated and ventilated mechanically even on warm days in May, so that in spite of open windows and doors in classrooms, the temperature was altogether

too high. Personal observation has shown it to be as much as 86° F. Every adult individual in the home and every school teacher in class must be mindful of the prevailing atmospheric conditions and should know how to bring relief when the conditions become unsatisfactory. To this end the ordinary thermometer is the best single guide for the average individual and it should be consulted frequently enough to avoid overheating at least. A temperature of 68° to 70° F. should be the maximum required for people in normal health.

Ventilation of assembly halls. — While natural ventilation is considered adequate for classrooms and homes, assembly halls, auditoria, and other meeting places where large numbers of people congregate, must usually be provided with mechanical ventilation. Professor Sedgwick, who was Curator of the Lowell Institute Lectures for many years, gave particular heed to the ventilation of Huntington Hall in Boston which seats 1,000 people. Mechanical ventilation was available, but his success in ventilating this large hall was largely attributed to his practice of keeping the temperature down to about 60° F. before the hall was occupied. People entering the hall at 7:30 P.M. would find the atmosphere cool and often wore their outer wraps until after 8:00 P.M. when the lecture began. By 8:15 P.M. the hall was quite comfortable, due, very largely, to the heat given off by each person. If the air became too warm, one or two windows were opened, sometimes only for a short period, in order to produce the necessary cooling effect. As a result, a thousand people would sit through an hour's lecture in perfect comfort, and few, if any, were ever tempted to fall asleep, even though the lecture or the lecturer might have been an aid to such pleasant forgetfulness. In many lecture halls and theaters fresh air is now supplied through a separate inlet duct under each seat and suitable provisions are also made for the constant removal of vitiated air. Nevertheless it would be desirable practice to keep each large assembly hall abnormally cool before the arrival of the audience and to make use of the thermometers in different parts of the hall at frequent intervals during the meeting to avoid overheating.

Ventilation in industry. — As far as industry is concerned mechanical ventilation is often absolutely indispensable. Where industrial dusts are created, or excessive temperatures prevail, or where the processes require conditioned air, reliance must be

placed on modern air-conditioning apparatus. This is essential for protecting the health of the worker and for insuring industrial efficiency.

Odors and health. — That bad odors are responsible for sickness and communicable disease is still one of the common popular beliefs. The ordinary individual may be perfectly oblivious to the dangers of raw milk or a polluted water supply, or even to the hazards of contact infection, but let a foul odor pollute the air of his environment, and at once the telephone of the health officer is besieged with violent complaints concerning the imminent dangers to the public health. In fact, the health officer is often required to divert his attention from more pressing and vital public health problems in order to alleviate or eliminate such nuisances as arise from foul odors.

The elimination of foul odors is eminently desirable from the standpoint of public decency and comfort, but it should be clearly understood that foul odors never give rise to diseases like typhoid fever, dysentery, tuberculosis, diphtheria, or any of the other communicable diseases. A foul odor may affect the appetite unfavorably, and produce nausea, vomiting, headache, dizziness, and general malaise, but these symptoms are temporary and disappear promptly with the removal of the cause or the senses gradually become dulled through long association with it. The odors from exposed garbage, a decomposing animal carcass, or from slaughterhouses, garbage reduction plants, incinerators, sewage treatment plants, stagnant sewage, decomposing excrement, and other forms of organic refuse are typical of the conditions that awaken the popular consciousness to the existence of a public health problem. A sensitive individual may find normal respiration disturbed under such conditions and his sleep may also be interrupted, but he will not suffer from communicable disease because of the foul odor itself.

There are certain odors associated with gases which are not only objectionable but actually dangerous to health and these should not be tolerated. Smelters and chemical plants which discharge enormous quantities of sulphur dioxide gas, which makes breathing difficult and dangerous, and which lays waste all vegetation within its zone of influence, represent a typical example. Oil refineries which discharge sulphuretted gases into the atmosphere represent a second illustration. A case in point

occurred in the vicinity of Providence in 1921, and the effects of the sulphur gases were discernible three or four miles away. The Massachusetts Department of Public Health has had a similar problem more recently in connection with an oil refinery in Everett. While the solution of the problem is difficult because of the sensitiveness of the olfactory nerves to gases like hydrogen sulphide and other sulphur compounds such as the mercaptans, nevertheless, in order to insure the comfort and safety of the residents in the vicinity of an oil refinery, a satisfactory way out must be found. The same holds true for the other pursuits of man which result in foul or objectionable odors. The extreme difficulty of the problem associated with sulphur gases in industry may be appreciated since hydrogen sulphide can be detected by smell when the concentration is only 0.0005 milligram per liter of air, and mercaptan, when the concentration is as small as 0.00000004 milligrams per liter of air.

Unfortunately the sense of smell is not a very good guide to danger when inodorous but nevertheless poisonous gases such as carbon monoxide are discharged into the atmosphere, for although this gas is highly toxic, it is free of any color or odor. Yet carbon monoxide poisoning is a serious public health problem today, partly because it is prevalent in illuminating gas and partly because it is found in the exhaust gases of internal combustion engines. Because of its significance this problem is discussed separately in another chapter.

There are many accounts of historic stinks, but of these perhaps two will suffice to show their profound effect on the popular psychology and incidentally their inability to produce disease. The first, which is taken from the *Chronicles of England, France, and Spain from the Latter Part of the Reign of Edward II to the Coronation of Henry IV*, by Sir John Froissart, v. I, p. 69, is of interest because it shows that a famous stink was more effective in the capture of a strong castle than all the ordinary implements of war then in use. It may be regarded as the forerunner of modern gas warfare which uses fatal disabling and demoralizing gases in the conquest of an enemy and in the subjugation of the civilian population behind the lines.

The Duke of Normandy Lays Siege to Thin-L'Eveque

"During the time the duke of Normandy lay in Cambray, the bishop and the inhabitants of that place informed him, that the Hainaulters had

taken by assault the strong castle of Thin; and they entreated him, out of love and honor, and by his regard to the country, that he would use his endeavors to regain it, as the garrison was a great annoyance to all the neighborhood. The duke then sent a fresh summons to his army, and got together a number of lords and men at arms, who were in Artois and Vermandois, and who had been with him in his former excursion. He set out from Cambray with all his host, and took up his quarters before Thin upon the river Ostrevant, ordering many large engines to be brought from Cambray and Douay. Among these were six of an immense size, which the duke had pointed against the fortress, and which flung huge stones into it day and night, beating down the roofs and the tops of the towers; so that it was not safe to remain in the chambers, and the people were obliged to take refuge in the vaults.

"This attack was severely felt by those within, and none ever suffered more for their honor than this garrison. 'The leaders,' encouraged their companions by saying, 'Gallant gentlemen, the earl of Hainault will surely come in a few days, and attack the French, to deliver us honorably out of our danger, and will give us his warmest thanks for having so boldly defended ourselves.' The besiegers by their engines flung dead horses and other carrion into the castle, to poison the garrison by their smell; and this distressed it more than anything else, for the air was as hot as in the middle of summer; they therefore having considered their situation, and that they could not long hold out from the horrible stench, proposed a treaty for a truce to last fifteen days, during which time they would let Sir John of Hainault, who was regent and governor of the country, be informed of their distress, and if they were not then relieved, they would surrender the place. This treaty was accepted, which gave great comfort to those within the castle."

The second case is the famous stink which arose from the Thames in London, in 1858 and 1859, due to improper sewage disposal, and according to Dr. Budd, whose account is recorded here, no serious results followed. In fact, it appears that the health of the people of London was actually better during this period than in previous years. While this is not presented in support of maintaining such intolerable conditions, it is evident that communicable diseases cannot be ascribed to their existence.

"The need of some radical modification in the view commonly taken of the relation which subsists between typhoid fever and sewage was placed in a very striking light by the state of the public health in London, during the hot months of 1858 and 1859, when the Thames stank so badly.

"The late Dr. McWilliam pointed out at the time, in fitting and emphatic terms, the utter inconsistency of the facts with the received notions on the subject. Never before had Nature laid down the data for the solution of a problem of this kind in terms so large, or wrought them out to so decisive an issue. As the lesson then taught us seems to be already well-

nigh forgotten, I may, perhaps, be allowed to recall some of its most salient points.

"The occasion, indeed, as already hinted, was no common one. An extreme case, a gigantic scale in the phenomena, and perfect accuracy in the registration of the results — three of the best of all the guarantees against fallacy — were combined to make the induction sure. For the first time in the history of man, the sewage of nearly three millions of people had been brought to seethe and ferment under a burning sun, in one vast open *cloaca* lying in their midst.

"The result we all know. Stench so foul, we may well believe, had never before ascended to pollute this lower air. Never before, at least, had a stink risen to the height of an historic event. Even ancient fable failed to furnish figures adequate to convey a conception of its thrice-Augean foulness. For many weeks the atmosphere of Parliamentary committee-rooms was only rendered barely tolerable by the suspension before every window of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the law courts were suddenly broken up by an insupportable invasion of the noxious vapor. The river steamers lost their accustomed traffic, and travellers pressed for time often made a circuit of many miles rather than cross one of the city bridges.

"For months together, the topic almost monopolized the public prints. Day after day, week after week, the *Times* teemed with letters filled with complaint, prophetic of calamity, or suggesting remedies. Here and there, a more than commonly passionate appeal showed how intensely the evil was felt by those who were condemned to dwell on the Stygian banks. At home and abroad, the state of the chief river was felt to be a national reproach. 'India is in revolt, and the Thames stinks,' were the two great facts coupled together by a distinguished foreign writer, to mark the climax of a national humiliation. But more significant still of the magnitude of the nuisance was the fact that five millions [of pounds] of money were cheerfully voted by a heavily taxed community to provide the means for its abatement. With the popular views as to the connection between epidemic disease and putrescent gases, this state of things naturally gave rise to the worst forebodings.

"Members of Parliament and noble lords, dabblers in sanitary science, vied with professional sanitarians in predicting pestilence. If London should happily be spared the cholera, decimation by fever was, at least, a certainty. The occurrence of a case of malignant cholera in the person of a Thames waterman early in the summer was more than once cited to give point to these warnings, and as foreshadowing what was to come. Meanwhile, the hot weather passed away; the returns of sickness and mortality were made up, and, strange to relate, the result showed, not only a death-rate below the average, but, *as the leading peculiarity of the season*, a remarkable diminution in the prevalence of fever, diarrhea, and the other forms of disease commonly ascribed to putrid emanations.

"After describing in scientific and forcible terms the unprecedented state of the river, Dr. Letheby adds: 'With all this condition of the Thames,

however, the health of the metropolis has been remarkably good. In the corresponding period of last year (*i.e.*, of the year 1857), the cases of fever, diarrhea, and dysentery, attended in the city by the medical officers of the unions, amounted to 293 of the former, and 181 of the latter; but during the past quarter (*i.e.*, the quarter of intolerable stench), they were only 202 of the former, and 93 of the latter!'

"The testimony of Dr. McWilliam, as medical supervisor of the water-guard and waterside custom-house officers, is still more to the point. The former to the number of more than eight hundred, 'may be said to live on the river, or in the docks, in ships, or in open boats; and the latter, numbering upward of five hundred, are employed during the day in the docks, or at the various wharves of the bonded warehouses on each side of the river.' After stating that the amount of general sickness among these men was below the average of the three preceding years, and considerably below that of the forms of disease (including diarrhea, choleraic diarrhea, dysentery, etc.), which, in this country, noxious exhalations are commonly supposed to originate, we find the addition during the four hot months of the year from this class of complaints 26.3 below the average of the corresponding period of the three previous years, and 73 per cent less than those of 1857. In another passage this distinguished physician says: 'It is nowhere sustained by evidence that the stench from the river and docks, however noisome, was in any way productive of disease. On the contrary, there was less disease of that form to which foul emanations are supposed to give rise than usual.

"Before these inexorable figures the illusions of half a century vanish in a moment." *

Dr. Ord reported to the Privy Council in 1859 that in 1858 (the year of the worst stench) steamboat men on the Thames suffered severely from languor, headache, sore throat, nausea, giddiness, mental confusion, etc. (in other words from symptoms of poisoning). In 1859 the river was much better, and very few such symptoms occurred: "The greater weekly mortality has not coincided with the greater development of the stench, our most ready measure of the foulness of the stream. . . . In both years the presence of sulphuretted hydrogen in the river atmosphere was shown by the rapid blackening of paper soaked in solutions of lead, and by the discoloration of the paint of vessels." †

The solution of the odor problem depends on the nature and source of the objectionable condition. Body odors are matters of personal hygiene and can be eliminated through the liberal use of soap and water and through the frequent changing of inner

* William Budd, *Typhoid Fever, Its Nature, Mode of Spreading and Prevention*, London, 1873, pp. 148–151.

† *Second Report, Medical Officer of the Privy Council, for 1859*, London, 1869, p. 55.

and outer clothing. Exposed garbage should be covered while in storage and in transit. Odors arising from decomposing heaps of organic refuse can be eliminated most effectively by prompt removal and satisfactory disposal. The methods employed have been described in the chapter on refuse disposal. Garbage disposal plants — *i.e.*, incinerators and reduction plants — can be operated without nuisance if properly designed and intelligently supervised, and both requirements are essential for public decency and municipal efficiency. The same holds true for sewage treatment plants. Streams and other bodies of water which receive such large amounts of unpurified sewage that a serious odor nuisance, particularly during the summer, is created, should be relieved by adequate preliminary sewage treatment. Odor nuisances in the home and in schools can usually be eliminated by providing adequate ventilation and by thorough cleanliness. The use of ozone or strong-smelling deodorants is unnecessary. Usually they simply mask one odor by creating another more powerful, and they tend to replace or delay cleanliness and ventilation, and hence must be considered undesirable. Odors arising from industrial processes should be eliminated at the source. Such nuisances must always be regarded as an industrial responsibility.

Although odors cannot be regarded as the cause of communicable diseases, they play a significant rôle in determining human comfort and public decency. Public health can no longer be limited simply to preventing the spread of communicable diseases, but the health officer must also assume some responsibility in abating nuisances which interfere with human comfort and public decency. Where obnoxious odors are due to the discharge of toxic gases, there the duty of the health officer is clear, and relief by abatement must be brought about without delay.

Sewer gas. — Many lay people and some sanitarians have long held that the escape of sewer gas into a house is responsible for various communicable diseases including typhoid fever, diphtheria, and puerperal fever. In general, this viewpoint has been discredited during the past twenty-five years, partly as a result of the statistical analyses of mortality records and partly through the negative findings of bacteriological examinations of sewer air. Nevertheless the impression still persists that sewer air is dangerous to health and gives rise to communicable diseases.

Actually, the health of sewer workers is just as satisfactory as

the health of laborers engaged in other types of work; and in spite of the extension of sewerage systems in the United States, a condition which should have increased the alleged hazards of escaping sewer air, there has been a noteworthy decline in the incidence and mortality of such diseases as typhoid fever, diphtheria, and others previously associated with sewer gases.

The old belief that sewer air may be a vehicle of pathogenic bacteria was given scientific support by the English bacteriologist, Horrocks, who, in 1907, reported that after introducing cultures of Bacillus prodigiosus — a harmless, red-pigmented, chromogenic bacterium — into the water closets of a military hospital at Gibraltar, the same organisms could be recovered by suitable bacteriological methods from the air in sewer manholes and in soil pipes. Naturally, if this condition is true for Bacillus prodigiosus, it follows that it may be true for disease-producing bacteria as well. In 1909, Professor C.-E. A. Winslow repeated the experiments in Boston for the National Association of Master Plumbers of the United States, using more accurate, as well as quantitative methods of analysis, and showed that the air of house drains was remarkably free of bacteria. Furthermore, the number of bacteria in the air above the sewage in a sewer depended entirely on the extent to which the sewage was agitated or violently disturbed. Normally, when sewage flows through a sewer, the air above it is fairly quiescent and its bacterial content is exceedingly small. The bacterial content of air collected near a busy street corner is very much greater and is far more likely to contain pathogenic bacteria. Since street air is not ordinarily considered a menace to health, sewer air, which is freer of bacteria, certainly should not be so regarded. While it is desirable to keep all objectionable gases out of the home, including foul sewer air, it is important to realize that the escape of small amounts of sewer air does not of itself represent a menace to health unless it contains specific toxic gases.

Any danger resulting from the inhalation of sewer air is due to the presence of certain toxic gases and not to its bacterial content. The gases given off in sewers are those resulting from the decomposition of organic matter and include methane, carbon dioxide, hydrogen, ammonia, and occasionally hydrogen sulphide. Carbon monoxide is also found sometimes in sewer air, but this is usually the result of illuminating gas escaping into the sewer. The dis-

charge of waste gasoline, benzene, and naphtha into sewers creates hazards because of their inflammable and explosive character and this condition must be given due consideration in protecting the lives of sewer workers. A sewer explosion may also prove to be serious for others who happen to be in the vicinity when the accident occurs. But the vapors of these volatile solvents, in the concentration normally found in sewer air, are not fatal or toxic when inhaled.

On the other hand, hydrogen sulphide gas is not only obnoxious to the sense of smell, but it is highly toxic. The presence of hydrogen sulphide in the air in the concentration of 7 to 8 parts per 10,000 is a menace to life, and a concentration of 10 to 15 parts in 10,000 produces death in a very few minutes. The danger from this gas can be eliminated by adequate ventilation of sewers, a condition that prevails normally in a sewer carrying swiftly moving sewage, and by allowing men to enter dead ends of sewers only after suitable precautions have been taken to insure the fitness of the air for human occupancy. The same precautions must be exercised to insure the safety of sewer workers against the possible presence of carbon monoxide or illuminating gas. Usually the danger from excess amounts of carbon dioxide and methane in sewer air is not significant.

Dusts. — The relationship of atmospheric dusts to health and disease has received extensive consideration and each aspect of the problem has had its staunch advocates. Industrial dusts are unquestionably potentially dangerous, not because of their bacterial content, but because they irritate the mucous membranes of the respiratory system and pave the way for the development of such diseases as the common cold, pneumonia, and tuberculosis. At one time the danger of atmospheric infection was considered so significant that the air of operating rooms was "disinfected" with carbolic acid sprays. This practice has long been abandoned in favor of aseptic surgery, which may or may not include air washing, for the danger of infection from the atmosphere under ordinary conditions is remote. The establishment of hospitals for the treatment of communicable disease in the heart of congested urban districts without any deleterious effects on the health of the people in the neighborhood is further evidence that the danger of aërial infection is very small. Similarly the treatment of different communicable diseases side by side in modern hospitals, with-

out experiencing cross-infections, indicates once more that communicable diseases are not air-borne.

In the presence of large amounts of infected dusts, containing living pathogenic bacteria, the danger of infection becomes very real. Similarly such dusts may produce disease if introduced directly into open wounds. But the most potent objection to atmospheric dusts, in the concentration normally present in the air, is that they represent a nuisance. Clothes soil more readily; the furniture and floor coverings in the home become covered with dust and grime, necessitating frequent cleaning; the skin and hair are readily soiled; varying amounts of dust are inhaled, thus favoring the development of certain respiratory diseases as well as the symptoms of hay fever and asthma; houses, monuments, public buildings, and other edifices become grimy; and on windy days the accumulated dust and dirt of the city streets are lifted into the atmosphere and whirled about until they enter the eyes, ears, nose, and mouth and create not only a nuisance, but a menace to health.

The dust particles in the atmosphere have their origin in the soil; in particles of plant and animal tissue including pollens and grains; in particles of salt derived from the ocean spray; in the products of combustion; in the products of abrasion; and in volcanic dusts. Some dusts, composed even of comparatively heavy particles, may be carried by the air over a distance of 1,000 to 2,000 miles or more. Smaller dust particles probably come into our atmosphere all the time from interstellar space. A certain amount of atmospheric dust is highly essential, for it limits the humidity of the air by forming nuclei for the raindrops and bringing about precipitation in the form of rain. Dust particles are also involved in the formation of fog, mist, and clouds which in turn help to control the temperature of the atmosphere. An outdoor atmosphere without dust therefore would be undesirable and an indoor dust-free atmosphere would be artificial.

The amount of dust in the atmosphere varies greatly with the time and place of sampling and with the instrument used. The number of dust particles in a given volume of air is determined by means of a konimeter, but there are so many different konimeters that comparative counts are of little value unless they have been made with the same instrument under similar conditions and with

identical precautions. A comparative study of the dust content of the air in 23 large cities of the United States was made by H. C. Murphy in 1927. The results are recorded in the following table.

TABLE 18

NUMBER OF DUST PARTICLES PER CUBIC FOOT OF AIR IN 23 AMERICAN CITIES

City	Dust Particles per Cubic Foot of Air
1. Boston	5,360
2. San Francisco	6,580
3. New Orleans	6,600
4. Denver	6,740
5. Washington	7,800
6. Des Moines	8,370
7. Minneapolis	8,470
8. Kansas City	9,700
9. New York	9,700
10. Philadelphia	9,880
11. Columbus	10,160
12. Toledo	10,700
13. Milwaukee	11,460
14. Baltimore	11,980
15. Buffalo	12,350
16. Louisville	13,340
17. Cleveland	13,840
18. Indianapolis	14,300
19. Chicago	14,300
20. Detroit	15,300
21. Pittsburgh	16,100
22. Cincinnati	16,770
23. St. Louis	17,600

While these dust counts indicate the condition of the atmosphere in many of the large cities of the United States at approximately the same time, they give no idea of the variations that occur in different portions of the same city, in different industries, and at different seasons of the year. Some of these variations may be observed in Table 19 on page 379.

The solid particles present in the atmosphere vary considerably in size, weight, and concentration. The smaller particles particularly are associated with certain respiratory diseases and with conditions of hypersusceptibility that make for hay fever and asthma. These particles are usually less than 15 microns in diam-

TABLE 19

NUMBER OF DUST PARTICLES PER CUBIC FOOT OF AIR FROM VARIOUS SOURCES *

Source	Dust Particles Per Cubic Foot
Out-of-doors, street level	118,000
Woolworth building, 10th floor	72,000
Woolworth building, 58th floor	23,000
Business office	128,000- 172,000
Department store, basement	94,000- 118,000
Pearl button factory	72,000- 139,000
Marble cutting shop [1]	590,000- 691,000
N.Y. subway platform	1,130,000- 2,320,000
Iron grinding room	14,800,000 48,700,000
Hat fur factory	435,000- 701,000
Rag sorting shop	215,000- 568,000
Mattress renovating shop	1,530,000- 7,140 000
Beating feathers dried with starch	160,000- 867,000
School lunch room [2]	258,000
School lunch room [3]	97,000
School lunch room [4]	1,090,000

[1] Compressed air chisels used
[2] 500 1500 pupils present
[3] Few pupils present Windows open
[4] Janitor sweeping

eter. (A micron or 1 μ is equal to 0.001 millimeter.) The following classification of atmospheric particles has been suggested by Drinker and Thomson.

CLASSIFICATION OF ATMOSPHERIC PARTICLES

Dusts.—Particles or aggregates of particles 1 to 150 μ in diameter, thrown into the air by mechanical agencies.

Fumes. — Particles 0 2 to 1.0 μ in diameter, derived from chemical or physio-chemical reactions such as ammonium chloride, lead, mercury, zinc and magnesium oxides, fogs, and acid mists.

Smokes. — Particles less than 0.3 μ in diameter formed by the incomplete combustion of carbonaceous matter and other substances, such as burning tobacco, oil, tar and gas.

The inhalation of mineral dusts over a long period of time results in irritation of the mucous membranes of the nose and throat and inflammation of the lungs, a condition commonly known as pneumokoniosis. Whether or not the inhalation of dust may cause communicable disease depends on many factors, one of which is the presence of virulent pathogenic bacteria. Ordinarily the danger

*From Hill and Campbell, *Health and Environment*, Longmans, Green & Co., 1925

of contracting disease in this way is slight because the concentration of dust particles is not excessive and the bacterial content of the air is small. Furthermore, pathogenic bacteria in the atmosphere are in an environment which does not favor growth or survival. On the contrary, the lack of proper food, the dehydrating effect of wind action, the lack of moisture, and the germicidal effect of the sun's rays, all tend to bring about a destruction of these organisms. Wherever the dust of normal air is held responsible for respiratory disease, it is important to eliminate contact infection, including droplet infection, as a more likely vehicle. Atmospheric dust helps to contaminate exposed foods, thus favoring decomposition, and in rare instances possible infection, but since exposed foods are invariably washed and cooked before being eaten, the dangers from atmospheric contamination are thus largely eliminated.

The bacterial content of air comparatively free of dust is exceedingly small. Pure air collected in mid-ocean yielded only 4 or 5 bacteria in 10 cubic meters. Air collected on the summit of Mount Blanc contained only from 4 to 11 bacteria per cubic meter. In 1934 Proctor * showed that bacteria, particularly of the spore-forming variety could be recovered from the air up to an elevation of 20,000 feet. Outdoor city air was found to contain only 32 bacteria per cubic foot, while outdoor country air contained 30 bacteria per cubic foot. Examinations of office air showed 80 bacteria per cubic foot, school air about the same amount, and factory air, 63 bacteria per cubic foot. All of these organisms were capable of development at 37° C. Definite figures for the bacterial content of air are of little value, however, since they vary so much with the season of the year, the concentration of population, wind action, and other factors. Winslow and Browne examined 1,037 samples of indoor and outdoor air and found that the total counts varied from 2 to 5,200 per cubic foot. A well-ventilated room contains fewer bacteria per unit volume of air than an unventilated room. Expired air is normally free of bacteria even though the air inspired may contain appreciable numbers of bacteria.

On the other hand, dusts, especially fresh dusts, are heavily laden with bacteria. More than 50 per cent of household dusts in metropolitan Boston, examined during the winter of 1929 to 1930,

* B. E. Proctor, "The Microbiology of the Upper Air," *Proceedings, Amer. Acad. of Arts and Sciences*, v. 69, No. 8, August, 1934, pp. 315–340.

were found to contain at least 1,000,000 bacteria per gram, and approximately 25 per cent of the samples showed a number in excess of 5,000,000 bacteria per gram. The maximum count obtained was 45,000,000 bacteria per gram, and the minimum count was 26,000 bacteria per gram. Street dusts showed counts in excess of 100,000,000 bacteria per gram, although Winslow and Kligler reported an average of 49,200,000 bacteria per gram for New York street dust. Household dusts should be removed by vacuum cleaners and then disposed of in a safe and satisfactory manner. Street dusts can be kept down by sprinkling and flushing, by oiling, by the use of auto vacuum cleaners, by avoiding dry sweeping, by providing smooth non-abrasive roads, by the further elimination of horse drawn vehicles, by providing rubbish containers wherever necessary and educating the people to use them, by requiring garbage men to collect organic household wastes without leaving droppings on the streets, by campaigns against spitting and against the use of streets as repositories for wastes, and by providing an adequate and efficient street cleaning service.

The smoke nuisance. — While the great sanitary movement of the nineteenth century resulted in the widespread purification of water supplies, the extension of sewerage systems and the more adequate disposal of municipal sewage, comparatively little has been accomplished as yet to prevent the daily pollution of the atmosphere with the smokes and fumes originating in the home and factory. That this is an acute problem may be readily observed in almost any sizable urban community. This aspect of atmospheric sanitation is receiving increasing popular attention, as is evident from the fact that numerous smoke abatement studies have been made in the United States, England, and Scotland, and also by the demand of public health authorities, physicians, engineers, and civic minded citizens that the smoke nuisance be eliminated.

The objections to a smoky atmosphere are as follows:

1. Smoke interferes with visibility and hence may favor industrial inefficiency and accidents.

2. Smoke prevents appreciable amounts of ultraviolet light from reaching the earth, a loss especially significant to the public health during the winter months in temperate regions.

3. Smoke injuriously affects or destroys the vegetation within its sphere of influence.

4. Smoke brings economic waste in its wake by soiling clothes, linens, tapestries, hangings, floor coverings, fabrics, and other household goods; by covering buildings and monuments with soot and grime, thus necessitating more frequent cleaning; and by destroying paint, metals, and other building materials.

5. Smoke produces a dismal and depressing atmosphere which exerts an unfavorable psychological effect on the individual, resulting often in unnecessary fatigue, irritability, lack of ambition and zest in living, decreased efficiency, and general dissatisfaction.

6. A smoky atmosphere favors a higher incidence and mortality from pulmonary disease, and affects the health and comfort of the individual in other ways.

Definition of smoke. — Smoke results from the incomplete combustion of any fuel and ordinarily consists of finely divided particles of carbon; it may and often does contain also, common coal tar, soluble salts in the form of a fine ash, ammonia or ammoniacal salts, sulphur dioxide and sulphur trioxide and their corresponding acids, sulphurous and sulphuric acids, hydrogen sulphide, and various other gases such as methane, carbon monoxide, and ethylene.

Reasons for existence of smoke evil. — While smoke was generated long before the advent of the use of coal, the smoke problem today is largely associated with the use of soft coal. The discovery of soft coal on the North American continent was first made in 1679 by Father Hennepin, a French Jesuit missionary. Hard coal or anthracite coal was first discovered near the site of Wilkes-Barre, Pennsylvania, in 1776. The extensive use of soft coal did not begin until after the Civil War, while the use of hard coal developed even more slowly because of the general ignorance of the proper way of burning it successfully. Today millions of tons of each variety are mined and used in the United States every year.

It is because the combustion of coal is incomplete and unsatisfactory that a smoke nuisance is created. Coals known as higher volatile coal, soft coal and gas coal, which are used largely by railroads, by industry, and in the manufacture of gas, are the most serious smoke producers. Low volatile coals, also known as semi-bituminous coals, which have a volatile or burnable gas content of not over 23 per cent, do not produce as much smoke as the higher volatile coals, and are sometimes referred to as "smokeless" coal. Fuels containing less than 9 to 10 per cent volatile matter

should be practically smokeless, particularly if combustion is properly performed.

Among the common gases given off from bituminous coal during the process of combustion are methane and ethylene. The ignition temperature of the first is between 650° and 700° C., while that for ethylene is above 300° C. If, in the process of combustion, these gases are liberated with a supply of oxygen insufficient to complete combustion, or if after being released they strike a cooler surface and the temperature is lowered below the ignition point, then their function is altered from heat producers to smoke producers.

Among the more important smoke producers in a community are the following: industrial plants of all kinds; electric power plants; gas and coke producing plants; steam locomotives; cabooses; dining cars; boats; ferries; steamships; and the heating systems of hotels, office buildings, hospitals, churches, schools, apartment and tenement houses, and private homes. Smoke is also produced wherever steam engines are used in construction work, in mining, and in other industrial pursuits. Fire-fighting apparatus equipped with steam engines have also been responsible for producing objectionable quantities of smoke. The moving automobile, the burning dump, the burning of leaves and rubbish, and forest fires, all help to pollute the atmosphere with smoke.

Anthracite or hard coal is also known as smokeless coal. Because of its hard texture it does not release particles of carbon during combustion, and its low volatile content likewise diminishes the possibility of producing smoke. Hard coal is more apt to give rise to white smoke, when smoke is produced, while soft coal and oil, improperly consumed, give rise to black smoke, which is largely responsible for the smoke nuisance. White smoke owes its color to small drops of water condensed from the water vapor formed in the burning of coal.

According to estimates made in 1928 by the U.S. Department of Commerce, the economic cost of the smoke nuisance in the United States is about $500,000,000 a year. The cost is not evenly distributed, since some communities suffer more than others, and some areas within a large city suffer less than other districts in the same community. The amount of smoke pollution in the atmosphere can be determined by drawing a known volume of air through filter paper and observing the extent of the resulting discoloration. Another way of measuring atmospheric pollution of

this sort is to ascertain the total amount of soot deposited in terms of tons per square mile per year. Numerous observations of this sort, made in England and Wales during 1921–1922, showed that the amount of soot deposited from the air of urban communities varied from 70 to 700 tons per square mile per year, with the mode around 300 tons per square mile per year.

The influence of industry on the smoke or soot content of the atmosphere is indicated by the following observations. The amount of soot deposited from the air in the industrial center of Leeds, England, was found to be equal to 539 tons per square mile per year, while air from a suburban residential section of Leeds yielded only 26 tons of soot per square mile per year. Similarly, while the air in the center of London was yielding 426 tons of soot per square mile per year, air from Sutton, Surrey, just outside of metropolitan London, yielded only 58 tons per square mile per year. Most people have observed the clearness of country, mountain, or sea air in contrast to the heavy, dirty, soot-laden air of the city. The data quoted above give some idea of this difference in quantitative terms.

Smoke and visibility. — Smoke in the atmosphere, especially when combined with mist to produce fog, brings about a great loss in daylight. This is particularly true during the colder months of the year. A recent study of the decrease of light by smoke made in New York City by the U.S. Public Health Service showed at the lower end of Manhattan during January, 1927, an average loss of daylight on sunny days equal to 42 per cent at 8:00 A.M. and 18 per cent at noon. As the year advanced, less daylight was lost, the loss in June being 33 per cent at 8:00 A.M. and only 6 per cent at noon. These data indicate the loss of daylight due to smoke only on clear and sunny days. On foggy days the loss was much greater. The loss of daylight due to smoke is greatest during the early morning and late afternoon hours and is least at noon. The loss is also greater in winter than in summer. The business section of Pittsburgh had 90 per cent less daylight than that found in the surrounding open country.

In Washington, observations made by the U.S. Public Health Service showed that at noon on a bright day in midsummer, the illumination seldom exceeds 10,000 foot-candles, whereas in midwinter at noon on a bright day, it seldom exceeds 3,500 foot-candles. The difference on sunny and cloudy days is illustrated by the

following data. In December, 1924, the average illumination on cloudy days was found to be about 23 per cent of that on sunny days, while in June, 1925, this ratio was 26 per cent.

The smoke of large cities acts as a blanket, forming mists and fogs, increasing the relative humidity, diminishing convection currents, curtailing the temperature range, and making the summer nights intolerably hot and uncomfortable. While the effects of smoke on industrial efficiency and on the joy of living have not been evaluated, the exhilaration experienced with the arrival of clear, bracing, sunny weather, testifies to their significance and reality.

Smoke and the curtailment of ultraviolet light. — As the prevalence of smoke in the atmosphere cuts out a considerable proportion of the available ultraviolet light this condition assumes public health significance, especially during the colder months of the year when the number of sunlight hours in temperate regions is few, and the amount of ultraviolet light available is small even under the best atmospheric conditions. The amount of ultraviolet light available in large cities and industrial areas varies from 25 to 60 per cent of that found in residential suburban communities and in small but non-industrial cities. This is a measure of the loss due to smoke. In Chicago, the Weather Bureau reported that the amount of sunshine recorded in 1929 was 12 per cent less than that reported in 1925. In 1929, the Chicago Health Department reported that only 50 per cent of the ultraviolet light observed on the roofs of tall buildings in that city reached the street level.

Effect of smoke on vegetation. — Animal life is fundamentally dependent on plant life, and conditions favorable to the growth and development of plants (foods) must prevail if animals are to live. The great lumber industry is based on the continued growth of plants. Plants also provide shade and coolness, an atmosphere lower in carbon dioxide and richer in oxygen, and form the basis of a pleasing and aesthetic environment.

For these reasons plant life must be preserved and the conditions favoring plant growth fostered. The presence of smoke and soot in the atmosphere, however, has an unfavorable effect on plant growth. The mechanism by which plant growth is inhibited has been somewhat in doubt. Some believe that the stomata of the leaves become mechanically clogged with the particles of carbon introduced into the air thus seriously impairing or preventing

respiration which results in death. Actual observation, however showed that only a small per cent of the stomata becomes clogged, and that respiration is not materially affected. Injury to plant life is accomplished through the water-soluble salts found in smoke ash and the water-soluble toxic gases like sulphur dioxide and sulphur trioxide. The tar found in smoke is also toxic to plant life as are some of the other gases such as ethylene, carbon monoxide, benzene, hydrogen suphide, and carbon bisulphide.

Economic importance of smoke. — That smoke curtails visibility and increases the use of artificial light must now be apparent. But smoke begrimes, defaces, decolorizes, destroys, and corrodes the exteriors and interiors of buildings and their effects, whether they be made of brick, stone, marble, metal, wood, or concrete. Smoke defaces works of art and public buildings and creations of lesser significance. Smoke soils the clothing one wears, the furnishings in the house — the rugs, hangings, chairs, pictures, etc., the merchandise in the shops and windows. This increases the laundry and dry cleaning bill in the home and causes a serious depreciation in the value of goods in the stores. Smoke also affects metals and paints through the acids it contains, and this results in a heavy, annual economic toll. Painted surfaces must therefore be renewed with greater frequency, and corrosion of metals may proceed to a point of serious concern. Window screens made of iron wire also disintegrate more readily in a smoky atmosphere.

Effect of smoke on health. — It is impossible to state exactly the quantitative effect of smoke on health since no one exists in a smoky atmosphere all the time and the body possesses great powers of repair. Nevertheless there is a widespread conviction among sanitarians and physicians that a smoky atmosphere is unfavorable to good health. Some of the effects may be summarized briefly. In the first place smoke cuts out a considerable proportion of the available ultraviolet light and these rays are important to good health. Second, by diminishing visibility, the possibility of accidents, especially in industrial pursuits, is materially increased. Third, the filling of the lungs with smoke and soot makes normal respiration more difficult and in consequence such conditions as anemia, dyspnea, chronic bronchitis, and emphysema are favored. Smoke also irritates the eyes, producing redness and congestion of the conjunctiva. It inflames the nasal and pulmonary passages and favors the development of pulmonary disease, especially pneumo-

nia. Fourth, smoke is associated with the liberation of carbon monoxide and sulphur dioxide as well as other toxic gases, and the inhalation of these gases in adequate amounts may produce toxic symptoms, and in the case of sulphur dioxide injury to the delicate membrane lining the nose, throat, and lungs, may result. Finally, a smoky atmosphere produces an unfavorable psychological effect, resulting in poor mental hygiene with its diverse indirect but nevertheless real effects on health.

Measuring the density of smoke. — The density of smoke prevalent in the atmosphere or emerging from a chimney may be measured by comparison with the Ringelmann Smoke Chart prepared for the U.S. Bureau of Mines. Each index in the chart represents

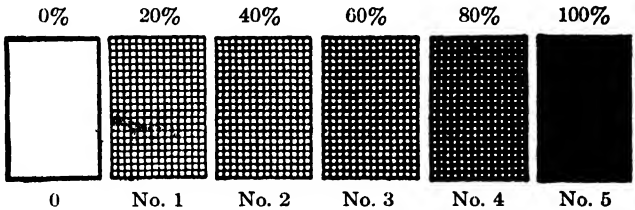


FIGURE 6. Ringelmann smoke chart, per cent density of blackness

the per cent of blackness and is a measure of the density of the smoke under observation. Smoke having a density of 60 per cent blackness or more — number 3 in the chart — is considered dense and is regarded as objectionable. In 1933 the photo-electric cell was adapted for the automatic recording of smoke in the atmosphere.

Smoke abatement and elimination. — Smoke elimination at present is a utopian dream, for it would mean the scrapping of all furnaces and stoves dependent on the use of coal as fuel and the elimination of open wood fires, of the burning of leaves and rubbish, and of other domestic sources of smoke. The use of gas, electricity and oil for domestic heating, the gradual use of gas and oil heating for industrial pursuits, the electrification of railroads and other phases of the national industrial life, aid materially in eliminating certain smoke evils and hence in curtailing the evil as a whole. However, further progress in smoke abatement can be accomplished through education and through the improved construction of stoves, furnaces, and other coal burning devices. For domestic heating purposes, if coal is employed, only anthracite or semi-

bituminous coal or coke should be employed. Where soft coal is used an ample draft sufficient to insure a hot fire so that all the volatile ingredients may be burned completely, should be provided. In addition, every individual who stokes a fire should be instructed how to do it properly. After the fire is shaken to remove the ash, the live coals should be piled higher in back than in front, and fresh coal should be added to cover the burning fuel in front only. In this way the products of combustion will be ignited more thoroughly, and the amount of smoke liberated will be reduced to a minimum.

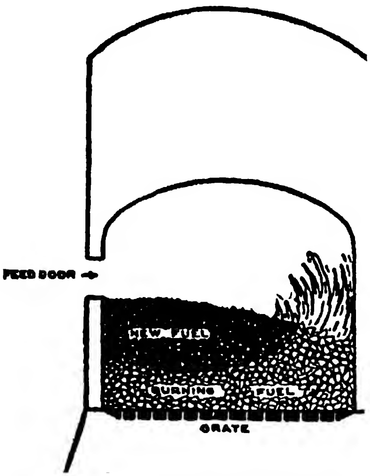


FIGURE 7. Fresh coal should be put on the fire as pictured above

Sunlight and health. — The dependence of all life on the radiant energy of the sun has been recognized for a long time but the profound relationship of sunlight to health has been rediscovered only in comparatively recent years. The demonstration by Huldschinsky in 1919 that exposure to sunlight or ultraviolet light prevented and cured rickets; the work of Rollier in Switzerland, started in 1903, on the beneficial effects of sunlight in the treatment and cure of tuberculosis, particularly of the nonpulmonary variety; and the experience of the race which showed that sunlight was beneficial in the treatment of skin diseases, are a few of the observations that have led to a fuller appreciation of the value of intelligent exposure to the direct rays of the sun.

But the sun was worshiped in ancient times partly because of its warmth, partly because it dispelled the darkness and its accompanying fears and partly because it was supposed to have the power to drive away the demons of sickness and to expel disease. As early as 431 B.C. Herodotus recommended the value of a sun bath for restoring muscular tone. Hippocrates, regarded as the father of modern medicine, was born in 460 B.C. and practised his art on the Island of Cos in the Greek archipelago. Here a great temple of health was erected to Aesculapius, God of the sun, med-

icine, and music, and it included a large gallery facing the south where presumably sun baths were a frequent practice. During the Roman era, too, the sun was an object of adoration, and a solarium, located, as a rule, on the roof of the house, was considered an essential part of every Roman home. Heliotherapy as a common practice became a lost art during the intervening centuries, until Finsen, in 1893, by curing skin tuberculosis, and Rollier in the twentieth century, focused attention once more on the value of sunlight as a therapeutic measure. Today, the importance of sunlight to health is generally recognized, and the "nudist movement" and abbreviated bathing suits are in part, at least, a popular response to this universal knowledge.

Composition of sunlight. — That sunlight is composed of rays of varying wave length is an established physical fact. Some of these rays are visible; others are invisible. Some have great powers of penetration; others have far less. Some rays can destroy living protoplasm; others lack this power almost completely. When sunlight is passed through a prism, it is broken up to form the colored spectrum, the colors being red, orange, yellow, green, blue, indigo, and violet in the order named. These are the visible light rays, but at each end of the spectrum there are invisible rays. The red rays have the longest wave length, and the violet the shortest of the visible rays. Beyond the red rays are the radio rays and beyond the violet rays are the health giving ultraviolet rays, the X-rays, and the radium rays. The cosmic rays which have been the subject of much scientific study in recent years have a wave length even shorter than the radium rays.

The wave length of light rays is measured in microns (μ) and millimicrons ($\mu\ \mu$). A micron is equal to 0.001 millimeter and a millimicron is equal to 0.000001 millimeter. The term Ångstrom unit (Å) is also employed, and is equivalent to 0.1 millimicron. In other words, one millimicron is equivalent to 10 Ångstrom units. The following classification of light rays based on variations in wave length was arranged by Luckiesh (Table 20).

Of the various radiations enumerated on page 390, the ultraviolet rays, as far as we know, have the most important relationship to health. These rays build up vitamin D in the body and aid in the absorption of calcium and phosphorus, elements required for building bone and dental tissue and for preventing or curing rickets These rays also tan the skin and are of value in the treat-

TABLE 20

CLASSIFICATION OF LIGHT RAYS

RAYS	WAVE LENGTH
Gamma or radium rays	0 – 0.01 $\mu\mu$
X-rays or Roentgen rays	0.01– 50 " "
Ultraviolet radiation	0 –390 " "
Extreme region	0 –200 " "
Middle region	200 –300 " "
Near region	300 –390 " "
Visible radiation	390 –770 " "
Violet	390 –430 " "
Blue	430 –470 " "
Blue-green	470 –500 " "
Green	500 –530 " "
Yellow-green	530 –560 " "
Yellow	560 –590 " "
Orange	590 –620 " "
Red	620 –770 " "
Infra-red radiation	0.77– ∞ μ
Near region	0.77– 20 μ
Intermediate region	20. –500 "
Extreme region	500. – ∞ "

ment of glandular and bone tuberculosis. They increase the germicidal power of the blood and thus promote resistance to infection. They are of value in promoting growth, in improving the general tone of the body, in destroying bacteria and other parasites in the environment, and in the successful treatment of certain skin infections. On the other hand, excessive exposure to sunlight, particularly during the summer months, or to ultraviolet light artificially produced, may prove injurious, and may result in serious burns, in the destruction of tissue and in fever. White men residing in the tropics appreciate the potential dangers of undue exposure to intense sunlight and accordingly protect themselves against these rays in order to preserve life and health. Brunettes withstand the tropics much better than blondes. The injurious effects of intense sunlight have even been cited to explain the abnormally high suicide death rate of California, and "May-madness" is recognized even in the temperate region of New England. As everyone knows, bright light is stimulating, whereas dim light is associated with peace and quiet, with meditation and religious aspiration.

Loss of sunlight. — The amount of sunlight is affected not only by the hour of the day and the season of the year, but also

by altitude, latitude, smoke, dust, and water vapor present in the air. A misty or foggy atmosphere, favored by smoke and dust, allows less sunlight to pass through than a clear one. The existence of fogs and mists also affects the atmospheric temperature since it is related to the dew-point.

Observations in Chicago in 1927 and 1928, over a period of sixteen months, showed that during the seven months from September 1 to April 1, the ultraviolet content of the atmosphere was exceedingly low, and that during November, December, and January, these rays, even in direct sunshine, were either entirely absent or too weak to give a satisfactory tanning dose in one hour. Such facts indicate how much sunlight is lost during the winter months because of smoke, fog, mist, and clouds, and they demonstrate the importance of obtaining sufficient ultraviolet rays during this period either from artificial sources directly, or indirectly from such food supplements as cod liver oil.

The loss of sunlight caused by atmospheric pollution and by low altitude and high water vapor content may be observed from the data presented below. During the winter months, London, for example, has only from 20 to 45 per cent of the amount of bright sunshine available at the same time in Oxford and Cambridge. The amount of sunshine available in the Swiss Alps will serve as a measure of the loss experienced in English and Scottish cities.

TABLE 21

DAILY DURATION OF BRIGHT SUNSHINE IN HOURS PER DAY IN CERTAIN BRITISH CITIES AND IN A SWISS ALPINE RESORT *

(Average results for 30-year period ending 1910)

City	Six Winter Months	Six Summer Months	Entire Year
Aberdeen	2.27 hours per day	5.09 hours per day	3.68 hours per day
Edinburgh	1.83 " " "	4.53 " " "	3 18 " " "
Glasgow	1 14 " " "	4.53 " " "	2.98 " " "
Newcastle-on-Tyne	1 56 " " "	4.13 " " "	2.85 " " "
Sheffield	2.08 " " "	5.11 " " "	3.60 " " "
Birmingham	1.71 " " "	4.40 " " "	3.10 " " "
Westminster	1.35 " " "	5 08 " " "	3.23 " " "
Oxford	2.42 " " "	5 84 " " "	4.13 " " "
Falmouth	2.85 " " "	6.69 " " "	4.77 " " "
Swiss Alpine Resort	5.28 " " "	6.86 " " "	6.05 " " "

* From Hill and Campbell, *Health and Environment*, Longmans, Green & Co., 1925.

The maximum amount of ultraviolet light is obtained from sunlight when the sky is clear and blue. Mountain sunlight is richer in ultraviolet radiation than sunlight at sea level because of the absorption of these rays by the atmosphere. In general, only about 50 per cent of the ultraviolet rays obtainable at an altitude of 5,500 to 6,000 feet reach sea level. Nevertheless the seashore is an excellent place for obtaining ultraviolet light in adequate amounts, since the ultraviolet rays are reflected from the water and the body is often scantily clad. The importance and recognized health value of sunlight should stimulate community efforts for smoke abatement and should create in each individual the urge to obtain its beneficial effects either through adequate exposure or through the use of cod liver oil, or similar oils, or through both methods combined.

Noise and health. The problem of city noise. — One of the concomitant effects of the industrialization, mechanization, and urbanization of life has been the marked increase in noise. To one not inured to the muffled roar of a great metropolis, sleep is difficult, if not impossible, even at night. Urban life is characterized by the use of innumerable appliances and constant activity, all of which have the power to contribute to the total amount of noise. Joseph Pulitzer — former publisher of the *New York World* — literally spent a fortune trying to make his New York home noise-proof, and although his house was comparatively quiet, it was impossible to keep out all the noises of the street. Residents who can afford it often seek relief from the noise and strain of city life by spending long week-ends in the country.

Sources of city noises. — In October, 1929, the Health Commissioner of New York City appointed a Noise Abatement Commission to inquire into all phases of the noise problem and to make recommendations for their abatement. A report entitled *City Noise* was published in 1930. It constitutes one of the best and most complete sources of information on the subject. According to this report the sources of city noise are associated with traffic, transportation, building operation, homes, streets, harbor and river, collection deliveries, and a final group listed as miscellaneous.

The traffic noises arise from the use of automobiles, motor trucks, buses, and motorcycles. The noises come from strident horns and shrieking brakes, from cut-outs, shifting gears, defec-

tive mufflers, rattling parts, rattling loads, sirens, bells, and the doorman's whistle which signals for the taxi-driver or milady's chauffeur.

Transportation noises arise from the operation of trolley cars, and subway, elevated, and railroad trains. The incessant rat-tat-tat of revolving turnstiles at subway and elevated stations, particularly during rush hours; the screeching of brakes and the rattling of heavy steel cars; the passage of trains or cars over intersections or switches in the rails; the constant grinding of steel wheels traveling at enormous speeds over steel rails; the endless shifting of cars; and the incessant use of whistles and bells and the exhausting of excess steam; — these are some of the noises associated with transportation.

Building construction and operation likewise contribute largely to the general bedlam. Perhaps the worst noise comes from the pneumatic drills and riveting machines. Anyone who has witnessed the construction of a modern skyscraper will appreciate the magnitude of the noise problem arising from these sources. Pile drivers, steam or gasoline hoists or shovels, and compressors often add to the din already present. Blasting operations, the incredibly large amount of loading and unloading of materials, the passage of trucks and teams, and the ever-present whistling, shouting, clanging of bells and release of steam under pressure, augment the medley of noise.

In the street one encounters the noises from radios and loud speakers emanating from stores, the noises of peddlers trying to sell their wares, the noises of children at play and from roller skates grinding over the sidewalk pavement, the noises of loiterers, street corner gangs, and a host of other sources. Nor is peace available even in the home, if one lives in an apartment, especially the large apartment houses of the congested cities. During the summer months, when the windows are open and each radio is functioning, when phonographs, pianos, and other musical instruments can be readily heard, when loud speaking and quarreling of children or adults add to the noises already present, conditions must be well-nigh intolerable. If to this be added the noises of gay night parties, telephone bells, doorbells, barking dogs, milk and food deliveries, collections of ashes, garbage, and rubbish, and the rattling of empty cans, it is easy to see how difficult it is for the tired and weary individual to find the rest, quiet and relaxation necessary for

effective recuperation from the daily toil. Other city noises include the whistles, bells, sirens, and horns of ocean liners and other river and harbor craft; the roar of airplanes, the deafening din of industry, the hubbub of the restaurant and the subdued or vociferous noises of the dance hall and the amusement hall.

The mere enumeration of the sources of noise in modern life — and the list is an incomplete one — lends weight to the importance of noise as a pressing public health problem. Happily, the public consciousness has been awakened and already much has been done to ameliorate some of its worst evils.

Relative importance of different noises. — In the New York study to which reference has already been made, an attempt was made to evaluate the offensiveness of various city noises. This was accomplished by a careful analysis of 11,068 complaints received as a result of a questionnaire, a summary of which is recorded below.

TABLE 22

CLASSIFICATION OF NOISE COMPLAINTS IN NEW YORK, 1930

Source	Number	Per Cent
Traffic (trucks, automobile horns, cut-outs, brakes, buses, traffic whistles, motorcycles)	4,016	36.28
Transportation (elevated, street cars, subway)	1,801	16.29
Radios (homes, streets, and stores)	1,367	12.34
Collections and deliveries (ash, garbage, milk, ice)	1,023	9.25
Whistles and bells (fire department, locomotive, tugs, steamships)	916	8.28
Construction (riveting, pneumatic drills)	819	7.40
Vocal (newsboys, peddlers, dogs, cats, noisy parties)	805	7.27
Others	321	2.89
Total	11,068	100.00

Relation of noise to health. — Although noise abatement is a health department activity, the relationship of noise to health is often only indirect. While loud noises do not cause fatal or dread diseases they do have effects which are considered prejudicial to health.

According to medical authority, there is ample evidence that exposure to constant loud noises impairs the hearing, and one

British authority is certain that occupational deafness exists. The sudden explosion of large paper bags in the presence of certain subjects at the Bellevue Hospital in New York resulted in raising the brain pressure four times higher than normal for seven seconds. Noise also interferes with sleep which is essential for good health and satisfactory vital resistance. Noise affects the nervous system and may lead to neurasthenia and psychasthenia. This is true for brain-workers particularly, who must have quiet for effective work. It has been demonstrated experimentally that noise interferes with normal efficiency in reading and typing. In the presence of noise, the mental worker must exert extra effort to work with the same efficiency and mental clarity which quiet makes possible

Measurement of noise. — In order to determine the intensity of noise, some objective index must be employed. In the New York studies a traveling noise laboratory was equipped with two types of noise measuring devices, one of which measured the deafening effect of noise, and the other, its intensity. The latter, called a "noise meter" picked up the noise directly through a microphone and registered its intensity on a dial.

The unit of loudness is known as the decibel. This has been described approximately as the slightest variation which the ear can detect in the level of sound. More accurately, the decibel (db) is the ratio between the intensities of two sounds. Thus if the intensities of two sounds are in the ratio of 10 to 1, they differ by 10 decibels. If the intensities of two sounds are in the ratio of 10^2 to 1, *i.e.*, as 100 to 1, the sounds differ by 20 decibels. In general, the number of decibels measuring the difference between two sounds is ten times the common logarithm of the intensity ratio.

Reducing this to a matter of common experience, it may be said that normal conversation carried on at a distance of three feet has a loudness of about 60 decibels. Since decibels do not measure absolute units of loudness, but a ratio of intensities, a small difference in the loudness as expressed in decibels means a tremendous difference in the intensities involved. Some idea of what this means may be gained from the following table, in which the left hand column represents decibels above the threshold of hearing, and the right hand column the actual intensity above the threshold of hearing.

TABLE 23

INTENSITIES OF SOUND ABOVE THE THRESHOLD OF HEARING MEASURED IN TERMS OF DECIBELS

Decibels	Intensities of Sound
10	10
20	100
30	1,000
40	10,000
50	100,000
60	1,000,000
70	10,000,000
80	100,000,000
90	1,000,000,000
100	10,000,000,000

The table makes clear the difference between loudness as measured by the ear (decibels) and intensity as measured by electrical instruments. While loudness to the ear appears to increase by simple arithmetical progression, the intensity increases by logarithmic progression, leaping from 10 to 10 billion while the loudness goes from 10 to 100. While the difference between 10 and 20 inches and 90 to 100 inches is the same, namely 10 inches, the difference between sounds of 10 and 20 decibels above the threshold of hearing and between 90 and 100 decibels is vastly different as far as the intensity of sound is concerned. In the former instance — sounds of 10 and 20 decibels — the intensity difference is 90; while in the latter instance — sounds of 90 and 100 decibels — the intensity difference is 9 billion.

Identification of noise in decibels. — Since noise is measured now in terms of decibels, and the decibel is not yet clearly identified in the minds of most people, some of the common noises (noted on the following page) may be evaluated in terms of decibels.

Noise abatement. — There is little doubt that many, if not all, of the city noises are unnecessary and can be abated. The education of the public to appreciate the harmfulness and needlessness of noise; the supervision and regulation of city noise as an official health department function; and the enlistment of scientific and engineering aid should do much to abate or eliminate noise. Noise often begets noise, and a bad situation is thus made worse. In the presence of noise conversation must be louder than normal, and the traffic policeman's whistle — if used at all — must be able to produce an audible sound above the din of traffic. On the other

TABLE 24

MAXIMUM NOISE LEVELS FROM DIFFERENT SOURCES IN TERMS OF DECIBELS
(New York City)

Hammering on steel plate (almost painful)	113 decibels
Automobile horn	102 "
Riveter	101 "
Subway	97 "
Blast of explosives	96 "
Steamship whistle	94 "
Elevated train	91 "
Motor truck	87 "
Lion roaring	87 "
Steam pile driver	87 "
Steam shovel	86 "
Police whistle	83 "
Street car	83 "
Passenger automobile (noisy)	83 "
Five noisy subway turnstiles	83 "
Radio loud speaker	81 "
Siberian tiger	80 "
Din of street traffic	60–80 "
Street noises	47 80 "
Squealing auto brakes	71 "
Non-residential indoor noises	32–72 "
Thunder (1 to 3 miles)	70 "
Passenger automobile (quiet)	65 "
Church bells	61 "
Residences—indoors	22–45 "

hand, a quiet, peaceful environment stimulates a quiet reaction. A person entering a church or cathedral treads softly and speaks in a whisper lest he be guilty of making unnecessary noise.

Much has been done to eliminate or abate some of the serious city noises. The elimination of cobblestone pavements and the use of pneumatic rubber tires on vehicles have done much to improve an otherwise impossible situation. It has even been suggested that in the future highways be surfaced with rubber as a further means of eliminating traffic noise. In metropolitan Boston, milk wagons formerly equipped with iron rims are now provided with pneumatic rubber tires, and while the noise of the horse's hoofs on the pavement has not been eliminated, the milk wagon itself passes silently by during the early morning hours and the half-wakeful sleeper is grateful for the change. In New York, the rat-tat-tat of the subway turnstiles has been largely eliminated at comparatively small cost. In 1933, the Interborough Rapid Transit Company of New York announced that a car had been constructed

in which the subway noise was reduced from 95 decibels to approximately 75 decibels. This new level is about as quiet as the ordinary Pullman car, while the noise of the ordinary subway car in New York equals that of Niagara Falls at the closest point visitors are allowed to reach. The windows of the new subway car are kept closed and all cracks are sealed. Forced ventilation is provided by power blowers through ducts equipped with silencers. Further reduction of subway noise can be accomplished by insulating and silencing the tubes as well as the cars.

The substitution of buses for street cars, the elimination of elevated trains by subway facilities, the construction of residences, office buildings, and factories with noise prevention in mind, the regulation of noises in the home, on the street, on the highway, in the harbor, and in the office, workroom, and factory should help to curtail the din created by city noise. Traffic control is now accomplished with silent lights, without recourse to the incessant blasts of the policeman's piercing whistle. Modern steel structures, including bridges and skyscrapers, can be constructed either entirely or very largely with quiet electric welding and without the aid of noisy riveting. The twelve-story office building of the Southern California Electric Company is 75 to 80 per cent welded. The fifteen-story building of the Boston Edison Company, the West Philadelphia plant of the General Electric Company, and the Homestead Hotel at Hot Springs, Va., are other illustrations of welded buildings. In 1929, 70 buildings in the United States and a score of bridges were constructed through the successful application of electric welding. The further extension of electric welding in heavy construction depends on the successful modification of building codes which require the use of rivets. Doubtless this change will be effected in time. The future of noise prevention and abatement is encouraging if the present popular interest in the subject is maintained.

CHAPTER XXII

CARBON MONOXIDE POISONING

The combustion of carbonaceous matter. — The discovery of fire and its application to the domestic and industrial pursuits of man brought in its wake a hazard to life which in recent decades has risen swiftly to a prominent position among the various causes of death. The problem has been greatly augmented by the introduction and almost universal use of the internal combustion engine. Whenever organic materials such as wood, coal, the various products of petroleum and other carbonaceous substances are burned, the combustion tends to take place in two stages. In the first stage combustion produces carbon monoxide (CO), a definitely poisonous gas, while in the second stage, carbon dioxide (CO_2), a comparatively harmless gas is produced. But if the supply of air in the combustion process is inadequate, or if the temperature of the gas as it reaches the outside air is too low, the second oxidation of the carbon does not occur, and only carbon monoxide is liberated.

In the combustion of coal a slightly different process may occur. If the bed of coals is too deep to permit the ready passage of air, or if the air supply is checked in any way, the combustion in the lower layer of red hot coal may proceed to the carbon dioxide stage; but this gas is reduced to carbon monoxide again as it passes through the upper layers of coal. In the stove or furnace this gas can be seen burning with a blue flame above the top layer of black coal, and while some of it is undoubtedly converted to carbon dioxide, the bulk of it, under the conditions described, will escape as carbon monoxide.

A third and important method of producing carbon monoxide occurs in gas stoves and gas water heaters. Manufactured gas, in use in many cities, is already rich in carbon monoxide, the amount present being at least 20 per cent. Even when natural gas, which is free of carbon monoxide and is rich in the relatively non-toxic gas methane, is burned, carbon monoxide may be produced in the burner itself. This occurs, not because of a deficient

supply of oxygen from the air, but because the flame is chilled when it comes in contact with a cooking utensil or a pipe containing cold water. The chilling stops the combustion at its first stage and results in the liberation of appreciable amounts of carbon monoxide. Occasionally in closed rooms such a stove or water heater may continue to produce carbon monoxide until the amount is sufficient to cause death, particularly if the water heater is not provided with a suitable flue to remove the gases of combustion. In order to minimize the amount of carbon monoxide produced by gas stoves and water heaters, only a blue flame should be used and the distance above the gas orifice should be increased to such a degree that the cooking utensil or water pipe will be just above and not in the visible flame.

In the past three decades the enormous use of motor vehicles, motor boats, airplanes, and other devices using internal combustion engines have become a source of destruction from carbon monoxide poisoning. Motor vehicles which have stood in a cold garage all night during the winter months require a rich mixture of gasoline in order to start. The combination of a cold motor and a rich mixture of gasoline results in exhaust fumes heavily laden with carbon monoxide. Henderson and Haggard estimate that the exhaust gases of an automobile will contain from 1 to 7 per cent or more of carbon monoxide depending on the richness of the gasoline mixture burned. Roughly, an automobile may produce one cubic foot or 28 liters of carbon monoxide per minute for every 20 horse power engine capacity. This is sufficient to render the atmosphere of a single car garage deadly within five minutes if the engine is run while the doors are closed. Accordingly great care must be exercised to have adequate ventilation through the use of open doors, in order to avoid poisoning or even death. The operator should not linger in the garage any longer than is required to remove the car into the open air.

Carbon monoxide poisoning as a cause of death. — The exact number of deaths due to carbon monoxide poisoning occurring in the United States annually is unknown. Deaths due to asphyxiation resulting from carbon monoxide poisoning, drowning, electrical shock, smoke poisoning, and acute alcoholism are in excess of 50,000, and a considerable portion of these are the result of carbon monoxide. Dr. H. S. Martland of Newark, N.J., estimated in 1934 that there are from 900 to 1,000 deaths in New York

City annually due to carbon monoxide asphyxia, and in his opinion a similar situation exists in every large city in the United States. In Massachusetts, in 1932, there were 173 deaths reported as suicide resulting from the absorption of poisonous gas and 95 deaths due to the accidental absorption of poisonous gas. In all, therefore, there were 268 deaths directly due to carbon monoxide poisoning. The significance of carbon monoxide asphyxia as a cause of death may be appreciated by comparing the number of deaths due to this cause with the number due to other causes. For example, in Massachusetts, in 1932, there were 25 deaths from typhoid fever and paratyphoid fever, no deaths from smallpox, 64 deaths from measles, 145 deaths from scarlet fever, 107 deaths from whooping cough, 107 deaths from diphtheria, 13 deaths from poliomyelitis, 229 deaths from diarrhea and enteritis under 2, and 360 deaths from influenza. Thus, in this long list, carbon monoxide asphyxia ranked second only to influenza, and was more important as a cause of death than many of the acute communicable diseases. It becomes even more important, however, when it is realized that carbon monoxide asphyxia is the favorite method of self-destruction and also that there are thousands whose resistance is being constantly undermined by subacute intoxication with carbon monoxide. It is difficult nowadays to find anyone in our great cities who does not show the presence of carbon monoxide in the blood. This is due to the constant pollution of the atmosphere with the exhaust gases from automobiles, to the extensive production of carbon monoxide in industry and in the home, and to the widespread use of tobacco. Dr. A. O. Gettler of New York found, in 1934, that the blood of laboratory workers, hospital patients, clerks, salesmen, and stenographers showed an average carbon monoxide content of about one per cent, while the blood of street cleaners showed an average of approximately 3 per cent.

It is generally agreed that the presence of more than one part of carbon monoxide in 10,000 parts of air, or 0.01 per cent, constitutes a health hazard. In view of the extensive pollution of the atmosphere of urban communities with the exhaust gases from automobiles, particularly in areas where traffic congestion is great, it is not surprising that deep concern is manifest regarding its seriousness. A survey was made by Bloomfield and Isbell of the U.S. Public Health Service in 1928 to obtain accurate information

on this subject. Fourteen of the largest cities in the United States, having a combined population in excess of 19,000,000, were visited, and 141 samples of air, obtained at the most congested intersections during the peak hours of traffic, were examined for carbon monoxide. The average of these tests showed the presence of only 0.8 part of carbon monoxide in 10,000 parts of air. Only 24 per cent of the samples showed a carbon monoxide content in excess of one part in 1,000 parts of air, and in only one location, a covered passageway, was the carbon monoxide content as great as two parts in 10,000. Since the carbon monoxide content of exhaust gases from automobiles, according to Henderson and Haggard, varies from a fraction of one per cent to 7 per cent or more, the findings of Bloomfield and Isbell indicate that a great dilution of this gas must occur promptly even in the most congested areas. These investigators conclude, therefore, that in the light of existing standards, exposure to carbon monoxide in city streets does not constitute a health hazard. The Committee on Poisonous Gases of the American Medical Association concludes, however, that the amount of carbon monoxide in city air is sufficient to contribute to the state of fatigue of those who breathe this contaminated air throughout the day. It is partly on this basis that the practice of relieving traffic officers at congested intersections after short intervals of duty has become common.

Illuminating gas as a source of carbon monoxide. — One of the factors responsible for the increase in the number of deaths from carbon monoxide asphyxia since 1890 has been the substitution of water gas for coal gas for heating and lighting. Prior to 1890, for example, Massachusetts prohibited the sale of illuminating gas which contained more than 10 per cent carbon monoxide. In that year, this statutory restriction was repealed, and, as Professor Sedgwick pointed out in 1911, the deaths from carbon monoxide poisoning mounted steadily with the increase in the use of water gas. Gas companies prefer water gas to coal gas because it is cheaper to manufacture, but the former is much richer in carbon monoxide and hence is more dangerous. Although water gas is always mixed with coal gas in varying proportions before it is delivered to the consumer, it still contains from 20 to 30 per cent carbon monoxide, an amount greatly in excess of that found in coal gas. The Committee on Poisonous Gases of the American Medical Association maintains that if the carbon monoxide content of city gas were

diminished by 50 per cent, the number of accidental deaths due to the absorption of this gas would be reduced to one-fourth or less of the present mortality.

When illuminating gas was first introduced it was derived entirely from the destructive distillation of coal. Such gas contained hydrogen, methane, and carbon monoxide, and occasionally also ethylene, acetylene, and carbon dioxide. The amount of carbon monoxide present in coal gas varies from 4 to 7 per cent, and because of this relatively low concentration, the fatalities due to its use are exceedingly low. Even today, London, Paris, and Berlin use coal gas instead of water gas. In such cases, even when accidental poisoning does occur, the likelihood of fatality is much less because of the low concentration of carbon monoxide.

In the United States, however, illuminating gas is obtained from water gas instead of coal gas except in those cities where natural gas is employed. Natural gas is free of carbon monoxide, but when the supply is limited or inadequate, manufactured gas, *i.e.*, water gas, is mixed with it. Water gas is prepared by blowing a current of steam through incandescent coke or coal. The steam is decomposed into hydrogen and oxygen, the hydrogen is given off, and the oxygen combines with the carbon in the coal or coke to form carbon monoxide. Water gas so produced burns with a pale, blue flame and contains about 40 per cent carbon monoxide; but it is usually enriched with various hydrocarbons such as benzene, toluene, and xylene in order to produce a luminous flame. This is diluted with coal gas and vaporized hydrocarbons before it is delivered to the consumer and in its final form may contain somewhat in excess of 20 per cent carbon monoxide.

The problem of diminishing the number of deaths due to accidental asphyxia with illuminating gas is associated with economics as well as public health. Water gas is less expensive than coal gas and people generally prefer to pay as little as possible for an essential commodity. If the public were willing to pay the extra expense associated with the use of coal gas, the fatalities due to illuminating gas could be greatly reduced. Unfortunately, too, illuminating gas is sold by the cubic foot instead of by its calorific content. If the latter basis for sale could be adopted, it would be possible to produce a gas low in carbon monoxide but high in calorific value and thus to control effectively the deaths now associated with manufactured gas of high carbon monoxide content.

The expansion in the use of illuminating gas is likely to aggravate the public health problem now associated with its use. In recent years gas has been used primarily for cooking purposes. for heating water, and for heating various industrial appliances. However, an effort is now being made to extend the use of gas for domestic heating, and although the cost of gas is greater than coal or oil, the increasing cost of the latter fuels and the great convenience and flexibility which the use of gas affords, has enabled it to make inroads in the field of domestic heating. This development is likely to expand in the future, necessitating higher pressures in the street mains and the use of reducing valves on the house supply. The dangers of leaks, breaks, and defective valves will be greatly increased and the hazards of accidental asphyxia materially augmented. The need therefore of a gas low in carbon monoxide content but high in calorific value is emphasized in the light of this eventuality.

The accidental deaths due to asphyxiation with illuminating gas fall into several groups. In the first group are the deaths resulting from the use of old or defective flexible tubing, or tubing which has become disconnected accidentally. The second group includes the deaths resulting from the use of cheap and defective gas appliances. A third group comprises the deaths resulting from the accidental extinguishing of a lighted burner when a pot or kettle boils over and the escaping gas is not shut off. The fourth group consists of the deaths resulting from the use of flueless hot water heaters, flueless gas logs, and flueless gas heaters in general, while the fifth group is associated with the use of quarter meters, where the meter is started by one individual and the gas jet or fixture in another part of the house or apartment has not been shut off after the flame was extinguished. The mere description of the conditions responsible for these fatalities suggests the requirements necessary to control these accidental deaths. The use of flexible hose in the home should be prohibited and fixed connections that are absolutely tight should be required. In the operation of gas hot water heaters the water coil should be kept clean. If it becomes coated with soot the latter is subsequently heated to incandescence, and a greater amount of carbon monoxide is thus liberated.

Another important carbon monoxide hazard in the home exists wherever open coal fires, coal stoves, and coal furnaces are in

use. Defective appliances or the premature closing of dampers may give rise to a carbon monoxide hazard of the first magnitude. It is only by intelligent operation of all appliances generating or liberating carbon monoxide and a conscious regard for the seriousness of breathing this poisonous gas that the dangers can be avoided.

Carbon monoxide hazards in industry. — As might be expected, the opportunities for carbon monoxide poisoning resulting from industrial pursuits are numerous, and sometimes the accompanying hazards are very great. This is likely to be the case where numerous gas appliances are in use, where leaky or defective tubing is employed, and particularly at the beginning of the work day when the appliances are still cold. The hazard is also greater during the winter months, as the windows are kept closed and ventilation is inadequate. A serious hazard also exists in public garages and service stations due to the constant starting and operation of motor vehicles. Where a motor is kept running for any length of time, the exhaust should be connected with the outdoors by means of a flexible hose.

Among the industrial pursuits where a serious carbon monoxide hazard exists, the following are some of the outstanding examples.

1. Industries where ironing machines, soldering stoves, and pressing machines are heated by gas, and where lead is melted in the same way.
2. The use of acetylene gas in welding.
3. The testing of gas meters, the repair of leaky or broken gas mains, and the location of gas leaks.
4. In public garages and service stations.
5. In blasting operations and in explosions, especially in mines.
6. In the care of factory furnaces.
7. In the iron and steel mills, especially among the coke oven workers, the core makers and furnace cleaners, and also because of leaky blast furnaces, gas valves, or mains.
8. In the distillation of coal tar.
9. In the manufacture of felt hats.
10. In the celluloid industry, during ignition and detonation.
11. In the manufacture of sulphur dioxide gas.
12. In the manufacture of soda from the smelting process.
13. In soldering, due to the fumes arising from the combustion of arseniuretted hydrogen.

14. In brass foundries, during the melting and pouring of the metal.

15. In kilns, from the fumes arising in the vicinity of burning kilns.

16. Among chimney sweepers, furnace cleaners, blacksmiths, enamelers, flue cleaners, linotype operators, foundry workers, incandescent lamp workers, lead smelters, patent leather makers, pottery workers, etc.

Properties of carbon monoxide. — Carbon monoxide is a colorless, tasteless, and practically odorless gas. It is lighter than air and burns with a pale, blue flame. Except for its ability to combine with the hemoglobin of the blood to the exclusion of oxygen, it would be a physiologically inert gas, and would be classed with nitrogen and hydrogen as a simple asphyxiant. Animals that have no hemoglobin are quite normal when placed in an atmosphere containing 80 per cent carbon monoxide and 20 per cent oxygen. The toxic action of carbon monoxide is therefore the result of the anoxemia that occurs after the oxyhemoglobin of the blood is converted to carbon monoxide hemoglobin. The end result is death from internal asphyxia.

Mechanism of carbon monoxide asphyxia. — In normal respiration, in an atmosphere free of carbon monoxide, the hemoglobin or red pigment of the blood combines with the inhaled oxygen to form a loosely-knit compound called oxyhemoglobin. This compound is carried by the blood to all the tissues of the body, the oxygen is released, and the oxygen requirements of the tissues satisfied in this way. But if the atmosphere contains carbon monoxide, carboxyhemoglobin is formed instead of oxyhemoglobin, since the combining power of the carbon monoxide and hemoglobin is about 250 times as great as the combining power of oxygen and hemoglobin. As a result a more stable compound, carboxyhemoglobin, is formed in the blood and the tissues are deprived of the oxygen they require. This results in internal asphyxia and subsequently in death.

When an individual is regularly exposed to small amounts of carbon monoxide he develops a tolerance to this condition which enables him to overcome its evil effects. Ordinarily there are from 4,000,000 to 5,000,000 red cells in each cubic centimeter of blood, but under the conditions described an increase in the concentration of red blood cells occurs in order that the oxygen

requirements of the body tissues may be satisfied. The number of red cells per cubic centimeter of blood may under these conditions be increased between 5,500,000 and 6,000,000. This phenomenon is known as polycythemia and the organ responsible for the increase in the red blood cells is the spleen.

There are at least two points of view to explain the toxic effects produced by the inhalation of carbon monoxide. The first and generally accepted theory was propounded by J. S. Haldane, the British physiologist, in 1895, and subsequently supported by Yandell Henderson in the United States in 1916. According to this view, the poisonous action of carbon monoxide is due to the deprivation of oxygen from the tissues of the body. Since the combination of carbon monoxide with hemoglobin is a loose one in spite of the greater affinity that hemoglobin has for carbon monoxide than for oxygen, the removal of a partially asphyxiated individual to the fresh air results in the gradual replacement of carbon monoxide in the blood by oxygen and the normal recovery of the individual. If there has been much delay in displacing the carbon monoxide from the blood, ill effects may follow, especially an intense headache due to edema of the brain and occasionally impairment of the heart and nervous system. These effects are not due to a permanent retention of carbon monoxide in the body but are the secondary results of the injury done to the brain and to the heart while carbon monoxide was in the blood, thus temporarily excluding the oxygen necessary for normal functioning.

The second point of view supported by A. P. Mathews in 1916, suggests that in addition to the direct combination of carbon monoxide with hemoglobin, the gas unites with other oxygen receptors and the resulting compound acts directly on the body cells. This point of view was supported in his opinion by the somewhat greater toxicity of carbon monoxide poisoning for mammals than an equivalent asphyxia by other gases, and also because carbon monoxide is toxic for some animals and plants which have no hemoglobin, but not for others. According to this theory, not only does internal asphyxia occur, but there is also a specific effect on the nerve centers and nerve cells. In acute cases this results in paralysis, and in chronic cases, in psychoneuroses. However, even in individuals seriously affected and who suffer unconsciousness, breathing does not cease. The breathing may be feeble and ineffectual, but it is probably never absent in those

cases that recover. For this reason artificial respiration should always be used in cases of carbon monoxide poisoning, even though consciousness may be absent. Carbon monoxide probably does not act as a cumulative poison, since it is discharged into the atmosphere sooner or later if the individual is removed to pure air and subsequently recovers. It is possible, however, that injuries done to the blood and hence to the tissues as a result of frequent exposures to carbon monoxide may be cumulative.

Factors affecting carbon monoxide poisoning. — The readiness with which an individual is affected by carbon monoxide depends on (1) individual susceptibility; (2) age and physical vigor, young and vigorous people being less susceptible; (3) exercise or physical activity favors carbon monoxide poisoning, as more carbon monoxide is absorbed by the blood. Men who have gone into mines following an explosion in order to rescue gassed comrades often suffer more from carbon monoxide poisoning because of their activity than those whom they rescue. Cases are also on record of individuals overcome with carbon monoxide in small garages, even while they were attempting to flee from a recognized danger. (4) Concentration of carbon monoxide in the atmosphere; (5) the period of exposure; (6) temperature and humidity, since carbon monoxide is absorbed more rapidly when the air is warm and humid; (7) the heat of combustion, since slow fires with insufficient air or a poor draft give off more carbon monoxide.

Seasonal incidence. — Carbon monoxide poisoning takes place more frequently in winter than in summer, since more fires are burned during cold weather, more carbon monoxide is liberated in starting cold motors and in heating cold gas appliances, and there is less indoor ventilation.

Quantitative aspects of carbon monoxide poisoning. — We are indebted to J. S. Haldane for some of the early and most reliable observations on the effects of varying doses of carbon monoxide on human and animal subjects. In experiments conducted on himself he found that no particular effect was observed until the hemoglobin was 20 per cent saturated with carbon monoxide. At this saturation any extra exertion such as running upstairs produced a very slight feeling of dizziness and some extra palpitation and hyperpnea. At about 30 per cent saturation, very slight symptoms such as a slight increase in pulse rate, deeper breathing, and slight palpitations became observable during rest; while run-

ning upstairs was followed in about half a minute by dizziness, dimness of vision, and abnormally increased breathing and pulse rate. At 40 per cent saturation, these symptoms were more marked, and exertion had to be made with caution for fear of fainting. At 50 per cent saturation, there was no real discomfort during rest, but the breathing and pulse rate were distinctly increased, vision and hearing impaired, and intelligence also greatly impaired. It was hardly possible to rise from the chair without assistance. At 56 per cent saturation it was hardly possible to stand and it was impossible to walk.

Haldane also found in experiments with mice that the presence of 0.06 per cent of carbon monoxide in air was sufficient to produce symptoms of poisoning, and that the presence of 0.22 per cent of carbon monoxide produced distinct symptoms in four minutes and death in 2 hours and 25 minutes. When he himself breathed air containing 0.12 per cent of carbon monoxide, *i.e.*, 12 parts in 10,000 parts of air, he felt palpitation of the heart in 33 minutes. In 90 minutes his vision and hearing were distinctly affected and he felt a slight tendency to stagger, with abnormal panting on running up and down stairs. In two hours, his vision and hearing were markedly impaired and there was some confusion of the mind with a throbbing headache. From his experiments Haldane concluded that 0.05 per cent of carbon monoxide, or 5 parts of carbon monoxide in 10,000 parts of air, is just sufficient to produce in time slight symptoms of poisoning both in men and mice, and that when the carbon monoxide content of the air reaches 0.2 per cent or 20 parts in 10,000 parts of air, the condition is very dangerous to man.

In the construction of the Holland vehicular tunnel under the Hudson River which joins Manhattan and Jersey City it was necessary to determine the maximum allowable carbon monoxide content of the atmosphere. The work was performed by Yandell Henderson and his co-workers who formulated the following statement concerning the probable effects of a given concentration of carbon monoxide gas in a given time.

1. When the time of exposure in hours, times the concentration of carbon monoxide in parts per 10,000, equals 3, there is no perceptible effect.
2. When the result is 6, there is a barely perceptible effect.
3. When the result is 9, there will be headache and nausea.
4. When the result is 15 or more, the conditions are dangerous.

5. If the volume of breathing is increased by exercise (even by slow walking, and correspondingly more by physical work) the rate of absorption of carbon monoxide is increased proportionately.

Henderson advised that if the Holland vehicular tunnel were so ventilated that persons passing through it would be exposed to not more than 4 parts of carbon monoxide in 10,000 parts of air for not longer than 45 minutes, they would experience no ill effect.

Apparently 2 parts of carbon monoxide in 10,000 parts of air may be breathed for a long time without producing perceptible symptoms. If the amount is increased to 4 parts in 10,000, no appreciable harm is done if the exposure is short. Exposure to 10 parts in 10,000 causes headaches and other symptoms of carbon monoxide poisoning, while exposure to 15 to 20 parts of carbon monoxide in 10,000 parts of air is dangerous. The New York State Labor law requires that every workroom in which carbon monoxide is given off or in any industrial process where carbon monoxide is produced, sufficient ventilation should be provided so that the amount of carbon monoxide in any portion of the room shall not exceed 0.5 part in 10,000 parts of air.

Use of small animals to detect carbon monoxide. — The time required for symptoms of carbon monoxide poisoning to appear in different animals is proportional to the respiratory exchange per unit of body weight. Thus a canary or a mouse which has a large respiratory exchange per unit of body weight will succumb to carbon monoxide gas in about one-twentieth of the time required for man. Since canaries are even less resistant to carbon monoxide than mice either may be used to detect the presence of carbon monoxide in poisonous proportions.

Symptoms of carbon monoxide poisoning. — The early symptoms of carbon monoxide poisoning have already been described. The ringing in the ears, dizziness, headache, throbbing temples, and a feeling of sleepiness and fatigue are strongly monitory. Later, there may be vomiting, a sense of oppression at the chest, palpitation, and an inability to stand or walk straight. Convulsions may or may not come on; the pupils are dilated and react slowly to light; the face is red; consciousness is gradually lost, but owing to the great loss of motor power, the individual though aware of danger is often unable to escape from it. The onset may be as sudden as a stroke of apoplexy. In animals, the heart-beat at first is

slow, while the blood pressure is high. In man, the action of the heart is frequently violent, even during stupor. When a man has recovered from the acute effects of carbon monoxide poisoning, his life is still in jeopardy for some days to come. He runs the risk of dying as late as 8 days after the poisoning, and after that he is in jeopardy from glycosuria and other serious sequelae such as apoplexy, softening of the brain, blisters, bedsores, and paralysis. Certain psychoneuroses may also develop varying from minor symptoms up to chorea and idiocy. When a person is removed from an atmosphere containing carbon monoxide there is a slow return to consciousness, but headache, nausea, and weakness persist for a long time. When death occurs it is the result of paralysis of the respiratory apparatus.

The specific symptoms of carbon monoxide poisoning correlated with the concentration of carbon monoxide in the blood are presented in tabular form by Sayers and Davenport in *Public Health Bulletin No. 150* published by the U.S. Public Health Service in 1925. The following table with certain modifications is obtained from that source.

TABLE 25

SYMPTOMS OF CARBON MONOXIDE POISONING CORRELATED WITH THE CONCENTRATION OF CARBON MONOXIDE IN THE BLOOD

Per Cent Saturation of Carbon Monoxide in the Blood	Symptoms
0–10	No symptoms
10–20	Tightness across the forehead; possibly slight headache; also dilation of the cutaneous blood vessels
20–30	Headache and throbbing in the temples
30–40	Severe headache, weakness, dizziness, dimness of vision, nausea and vomiting, collapse
40–50	Same as for previous concentration with greater possibility of collapse and loss of consciousness. The respiration and pulse rate are also increased
50–60	Collapse, unconsciousness, increased respiration and pulse rate, and coma with intermittent convulsions. The respiration gradually increases in depth up to a certain point, then decreases and finally ceases for about half a minute, after which it begins again as before
60–70	Coma with intermittent convulsions, depressed heart action and respiration and possibly death
70–80	Weak pulse, slowed respiration, respiratory failure and death

Diagnosis of carbon monoxide poisoning. — The diagnosis of carbon monoxide poisoning can be made quite readily by examining a little blood of the suspected person for the presence of carbon monoxide-hemoglobin by the Sayers-Yant method. This test was developed by personnel of the U.S. Bureau of Mines and the U.S. Public Health Service. The apparatus is small and compact, durable, and simple to operate; and its operation does not require scientific training. Nevertheless it gives accurate results both in the field and laboratory, and can be used to detect the presence of carbon monoxide in the air as well as the blood. The procedure is often referred to as the pyrotannic acid method. It is based on the fact that when normal blood, diluted with water, is treated with a solution of tannic and pyrogallic acids, a light gray-brown suspension is formed; whereas if blood containing carbon monoxide is treated in a similar manner, a light carmine suspension is produced. In any mixture of normal blood and blood containing carbon monoxide, the suspension will be a corresponding mixture of the two extremes of color. The apparatus consists of a set of color standards representing the different colors produced when known but varying amounts of carbon monoxide in combination with hemoglobin are treated with the tannic acid-pyrogallic acid solution. The color produced in a blood with an unknown amount of carbon monoxide when it is treated with the tannic acid-pyrogallic acid solution can then be matched with the known standards, and the amount of carbon monoxide present determined in this way.

The test is performed by removing 0.1 cc. of the suspected blood under aseptic conditions. The blood is obtained by pricking the skin on the upper side of the thumb near the nail, after the skin has been cleaned and sterilized with alcohol. The needle or dagger used to release the blood must also be sterile. With the aid of a carefully graduated pipette, 0.1 cc. of blood is withdrawn and diluted to 2 cc. or 20:1 with distilled water. The dilution is made in the same pipette, which has a bulbous reservoir for this purpose. The diluted blood is now introduced into a small test-tube, to which is added a measured amount of pyrotannic acid. The latter dissolves in the diluted blood and produces a specific color depending on the amount or concentration of carbon monoxide-hemoglobin present. By comparing the color produced in the tube under test with the available standards, the specific concentration of carbon monoxide in the blood can be readily determined.

The determination of carbon monoxide in the air. — The presence of carbon monoxide in a given atmosphere can be detected by the use of canaries or small animals such as mice. Canaries show signs of distress when exposed to an atmosphere containing 0.1 per cent carbon monoxide for 60 minutes. If the carbon monoxide content of the air is increased to 0.15 per cent, unfavorable symptoms will develop in from 5 to 30 minutes. If the carbon monoxide content of the air is increased to 0.2 per cent, unfavorable symptoms will develop in from 2 to 5 minutes. Canaries and mice therefore are good detectors of carbon monoxide when the concentration is around 0.2 per cent, but they are not satisfactory when the concentration is around 0.1 per cent or less. It is also true that small animals cannot be carried through an atmosphere containing carbon monoxide to a remote place where the test is to be performed without showing symptoms of poisoning before the proper time of exposure. Accordingly a more sensitive and more flexible method of determining the carbon monoxide content of the air is required. Recently (1931) the Boyce-Thompson Botanical Research Laboratories of Yonkers, N.Y., announced that the leaf of the tomato plant is more sensitive to carbon monoxide in the air than the canary, and suggested its possible use as a detector of carbon monoxide. In the presence of this gas the healthy tomato leaf wilts and droops.

The amount of carbon monoxide in the air can be determined accurately by a variety of chemical methods. The pyrotannic acid method of Sayers and Yant, described above, is one that may be so employed. In addition to the apparatus already described, it is necessary to have a sample bottle of at least 250 cc. capacity properly equipped with suitable rubber stopper, aspirator bulb, and scrubber. The latter is a tube of soda lime through which the air under examination is first passed in order to remove any gases present which might interfere with the test. Normal animal blood is substituted for human blood and is allowed to combine with the carbon monoxide present in the sample of air being examined. The resulting color is compared with the color standards.

A second method is the iodine-pentoxide process developed by Seidell in 1914 and utilized by M. C. Teague in 1921 in connection with the experiments conducted by the U.S. Bureau of Mines on the air of the Holland vehicular tunnel. With this apparatus the presence of as much as 2 parts of carbon monoxide per 100,000

parts of air can be determined. The method consists in oxidizing the carbon monoxide present by the use of iodine-pentoxide and determining either the amount of carbon dioxide formed or the amount of iodine liberated. The air is first treated by passing it successively through 20 per cent sodium hydroxide, concentrated sulphuric acid maintained at 160° C., a tube containing solid sodium hydroxide and finally the tube containing the iodine-pentoxide.

A third method, used exclusively to detect the presence of carbon monoxide in the air and not to determine it quantitatively, consists of a simple device recently marketed by the Mine Safety Appliances Company of Pittsburgh, Pa., under a license granted by the Electrical Research Products, Inc., of New York. The device is simple to use and is effective in detecting the presence of 0.03 per cent or more of carbon monoxide in the atmosphere, or an amount equal to 3 parts in 10,000. It consists of an ampule containing palladium chloride in a non-freezing solution of acetone and water. The ampule is made of glass and is surrounded with absorbent cotton. Around this a short string is attached, and this in turn is subsequently attached to a long string or wire immediately before the ampule is used. The ampule is held horizontally in both hands between the thumb and forefinger, then is crushed and pressed flat until the absorbent cotton becomes thoroughly and uniformly saturated with the palladium chloride solution. The moistened cotton is then lowered into the atmosphere to be tested, kept at the elevation of a man's head while he is at work, and allowed to remain in that position for at least 10 minutes. If carbon monoxide is present the cotton will turn dark. The amount of carbon monoxide present can be approximated by comparing the color obtained with a color chart provided with the apparatus.

Treatment of carbon monoxide poisoning. — Individuals seriously affected with carbon monoxide gas are almost always unconscious, but they are usually still breathing. This breathing may be feeble or ineffectual, but it is probably never absent in cases that recover. In persons rendered unconscious by electric shock, respiration suddenly ceases altogether, although the heart continues to beat for a brief period of time. Where unconsciousness is present, artificial respiration must be employed and probably the best means of starting respiration again is by the Schäfer or

prone-pressure method. Formerly the lungmotor or pulmotor was used for this purpose but these instruments have been largely discarded as they force air into the lungs and then actively suck it out. They have been replaced by the inhalator developed by Henderson and Haggard in the United States. This machine is provided with one or more cylinders containing 5 or 7 per cent carbon dioxide in oxygen, a mask that is fastened to the face of the victim of asphyxia, and suitable valves for the introduction of the gas mixture to the respiratory system and its subsequent removal.

The carbon dioxide is used to stimulate the respiratory center in the medulla of the brain, so that normal respiration may be resumed. The breathing of pure oxygen by persons having a concentration of 35 to 40 per cent of carbon monoxide in the blood causes the elimination of carbon monoxide from the blood four times as rapidly as breathing air. Breathing pure oxygen to which 5 or 7 per cent carbon dioxide has been added, under similar concentrations of carbon monoxide in the blood, causes deeper and more rapid breathing, and results in the elimination of carbon monoxide from the blood five to six times as rapidly as breathing normal air, and about twice as fast as breathing pure oxygen. The rate of elimination of carbon monoxide from the body is between 30 to 60 per cent per hour, depending upon the bodily activity of the individual and the amount of oxygen taken into the body.

The object of inhalational treatment is to remove the carbon monoxide from the blood as rapidly as possible. The asphyxiated person should not be moved except to get him into an atmosphere free of carbon monoxide. If the victim is not breathing or the breathing is weak and intermittent or present only in occasional gasps, artificial respiration by the prone-pressure method should be started without delay and should be continued until spontaneous breathing returns or until death is fully established. Spontaneous breathing is restored more promptly if while one operator is performing the prone-pressure method of resuscitation, another simultaneously administers the inhalation of the oxygen and carbon dioxide mixture.

If the victim is breathing, as is often the case even in dangerously severe asphyxia, artificial respiration should not be used. Instead, the inhalation of oxygen and carbon dioxide should be begun immediately. If the mixture of gases is not available, oxygen alone should be used.

It is important to keep the patient warm in order to tide the body over a period of low vitality. If he has to lie on the ground or pavement coats or blankets should be put under him. This is more important than to put them over him. Hot water bottles, hot bricks, and other devices may be employed to keep the body warm. The inhalation should be continued until spontaneous breathing and consciousness have returned and the pulse is normal and quiet. The patient should be kept at rest, lying down in order to avoid any strain on the heart, and should not be allowed even to sit up until he is fully normal again.

In cases of carbon monoxide poisoning the use of stimulants such as hypodermic injections of caffeine, sodium benzoate, or camphor in oil should be employed only rarely if at all. Similarly, blood transfusions, though not harmful, are quite useless. Such transfusions are performed only when the patient is still unconscious several hours after asphyxiation. Most of the carbon monoxide, even in a patient not treated by inhalation, has by that time been eliminated from the blood. The continued coma is due to edema of the brain and other post-asphyxial injuries to the nervous system which a blood transfusion does not aid.

The Schäfer or prone-pressure method of resuscitation. — In the prone-pressure method of artificial respiration the diaphragm is alternately compressed and released. The application of pressure forces the air out of the lungs, and the release of pressure produces a natural inspiration of air. In this way the dangers inherent in the use of positive pressures, such as with machines, especially in the hands of inexperienced operators, are avoided. Furthermore, the Schäfer method of resuscitation can be applied immediately, at a time when the saving of minutes is precious. To depend entirely on the lungmotor, pulmotor, or inhalator may result in a fatal loss of time.

As soon as the patient suffering from carbon monoxide asphyxia is discovered he should be removed to an atmosphere entirely free of the gas. Foreign matters present in the mouth, such as tobacco, false teeth, and the like, should, if possible, be removed. If this is not possible precious time should not be lost attempting to do so by force. The patient should be placed on his belly, with one arm extended directly overhead, and the other arm bent at the elbow. The head is rested on the bent arm, with the face resting on one side, so that the nose and mouth are free for breathing purposes.

The operator should straddle the prone patient at the hips, and assume the kneeling position, so that his knees are just below the patient's hip bones or openings of the pants' pockets. The palms of the hands are then placed on the small of the back, with the fingers over the ribs, the little finger just touching the lowest rib, the thumb alongside of the fingers, and the tips of the fingers just out of sight. While counting one, two, and with arms held straight, the operator should swing forward slowly so that the weight of his body is gradually but not violently brought to bear on the patient. This should take from two to three seconds. While the operator counts three he swings backward so as to remove the pressure, and returns to a vertical kneeling position with his hands completely removed from the body. He rests while counting four and five, and then repeats his pressure and release until respiration has become a normal function once more. A complete cycle of pressure and release should require four or five seconds, and there should be therefore from 12 to 15 complete cycles every minute. Care must be observed not to go through the complete cycle more rapidly than specified.

While artificial respiration is in progress an assistant should loosen any tight clothing about the patient's neck, chest, and waist, and the patient should be provided with a hot water bottle at the feet and with blankets to keep him warm, care being taken to follow the precautions mentioned under the inhalation method of resuscitation. Artificial respiration should be continued without interruption by one or more operators, until natural breathing is restored, if necessary for four hours or longer, and until a physician declares that rigor mortis, or the stiffening of the body, has set in. If natural breathing stops after being restored, artificial resuscitation should be resumed again.

The use of ozone in combating carbon monoxide. — Various attempts have been made to combat the carbon monoxide hazard in public garages and service stations through the use of ozone, but the results have been unsatisfactory. The use of ozone is based on the assumption that it will combine rapidly with carbon monoxide and transform it to carbon dioxide. This assumption is false for it takes at least three days for the reaction between ozone and carbon monoxide to be completed at ordinary room temperatures. Tests made in service stations where ozonizers were in use, showed appreciable amounts of carbon monoxide in

the atmosphere, and in two cases, amounts as high as 3 and 4 parts per 10,000 parts of air. It should also be remembered that ozone itself is a poisonous gas, in fact more poisonous than carbon monoxide. Furthermore, even if ozone were effective against carbon monoxide it would still be undesirable to use it, for the amount of ozone recommended is 5 parts per million, and this could react only with 15 parts per million of carbon monoxide. Since 45 parts per million of carbon monoxide can be tolerated by humans quite readily, it is obvious that there is no advantage in removing 15 parts per million from the air. Still another disadvantage associated with the use of ozone is that the emphasis is placed on cure rather than prevention. Every effort should be made to prevent the introduction of carbon monoxide into the atmosphere and to purify it constantly by adequate ventilation. Thus alone can the dangers from carbon monoxide asphyxia be combated effectively.

CHAPTER XXIII

THE RELATIONSHIP OF HOUSING TO HEALTH

Reasons for existing housing evils. — Doubtless every forward-looking person has a sympathetic attitude toward the housing problem, and were it in his power to do so, every slum district would be abolished and every family would be satisfactorily housed. That a housing problem exists is the result of many factors. The rapid growth of the United States since 1880, resulting in the formation of large and congested urban areas; the lack of adequate and desirable housing facilities in these centers during this period; the inadequate facilities for transporting people rapidly and cheaply to and from work; the herd instinct exhibited so frequently by newly arrived immigrants ignorant of our language and mode of life; the greed of landlords; the lag between the creation of housing evils and the enactment of suitable corrective housing legislation; the economic inability of ordinary workers to afford satisfactory housing facilities; the lack of city and town planning during the period of greatest growth; and the abuse of existing housing facilities through ignorance, have all contributed to create the manifold housing problems found in the United States today. But the housing problem is not synonymous with the slum problem of our great cities. While city slums represent a problem of great magnitude, and must be solved in time, many serious housing evils exist in the smaller cities and towns and sometimes they seem to be particularly acute on the prairies, on farms, near oil fields, or in other places where land and light and fresh air are abundant.

Housing and the family. — Anything which tends to foster family life, and to make it delightful, comfortable, and happy, makes for a stable, contented people. The house, which is the environment of some members of the family for 24 hours a day and for all members at least 8 hours a day, should be healthful, attractive, pleasant, and comfortable, and a place that stimulates interest and pride.

Model housing schemes have scarcely touched the housing problem. — Housing for families of small means has been a sub-

ject of interest to health and social workers, to philanthropists, to industrialists, to legislators, to clergymen, and to others interested in promoting the public welfare. Although numerous model housing ventures have been undertaken in various parts of the United States, it is important to remember that the facilities provided represent but a small part of the new construction provided simultaneously. In 1917 Lawrence Veiller estimated that "philanthropy had provided only 0.7 per cent of the improved housing conditions in New York during a period of 40 years of model, tenement growth." Obviously the housing problem can hardly be affected in this way, although model tenements or model houses are useful for purposes of demonstration, publicity, and education.

Among the model housing demonstrations initiated in the United States since 1917 are the following.*

1. Government houses built by the U.S. Housing Corporation at Bridgeport, Connecticut, for munition workers.
2. Government houses built by the Emergency Fleet Corporation of the U.S. Shipping Board at Hog Island, Philadelphia; Camden, N.J.; Sparrow's Point, Md.; and Wilmington, Del.
3. A satellite garden city at Mariemont, Ohio.
4. A satellite garden city at Radburn, N.J.
5. Coöperative houses built by the Amalgamated Clothing Workers of America near 200th Street and Moshulu Parkway, Bronx, and on Grand Street on the East Side of Manhattan.
6. The houses built by the Metropolitan Life Insurance Company in the Borough of Queens to eliminate commercial profit.
7. The houses built by the City Housing Corporation in the Borough of Queens, known as Sunnyside Gardens.
8. The houses built by Mr. John D. Rockefeller, Jr., at Bayonne, N.J.; at Avenue A and 65th Street, New York City; the Thomas Garden Apartments at Mott Avenue and 158th Street, Bronx; and the Paul Lawrence Dunbar Apartments for negroes at 7th Avenue and 149th Street, New York City.
9. The Lavanburg Homes at Goerck Street on the East Side of Manhattan.
10. The Michigan Boulevard Garden Apartments for more well-to-do negroes in Chicago, built by the Julius Rosenwald Fund.

The difficulty of evaluating the health significance of poor housing. — Invariably, one of the main arguments of those interested in promoting better housing conditions is the significant

*From information given in *Recent Trends in American Housing*, by Edith Elmer Wood, 1932.

relationship between housing and health. Extravagant claims have been made in the past concerning the relationship between housing and tuberculosis, typhoid fever, diphtheria, and other communicable diseases. Similarly, poor housing conditions have been linked up with high infant mortality rates, high general death rates, and with stunted height, weight, and growth in children. Usually death rates and morbidity rates for those sections of a city where poor housing conditions prevail, have been compared with similar rates for the better areas, and the conclusion drawn that the more unfavorable disease and mortality rates in the former were due to poorer housing conditions. Obviously such a simultaneous occurrence of phenomena may be purely accidental, and it does not follow that they are related to each other. Even if some relationship did exist, poor housing might not be the only factor or the most significant factor in high morbidity and mortality. Unfortunately, poor housing is invariably associated with poverty, with ignorance, with inadequate and unsatisfactory food, with scanty or ineffective medical and nursing service, with long hours of toil and hard labor, with cold, dampness, and exposure, with unhygienic living, and various other factors of real significance to health. Under the circumstances, it is impossible to say definitely that bad housing *per se* is responsible for disease and death. There are too many uncontrolled variables involved in evaluating the health significance of housing to warrant such a simple conclusion.

Bad housing and high mortality are not necessarily related. — On the contrary, reliable data are available that show no correlation between bad housing and tuberculosis, or infant mortality or the stunting of children. Tuberculosis surveys made by Horwood in Philadelphia (1922), Boston (1925), Cambridge (1927), and Holyoke (1929) demonstrated that the mortality from tuberculosis was actually lower in the most congested wards of these cities, where poor housing conditions prevailed, than in other sections of the same city, where congestion was less and housing conditions at least as good or better. In these instances the racial factor was of primary significance. Similarly, the infant mortality rates among certain racial groups on the East Side of New York are very much lower than those that prevail among other groups living either in the same district or in other parts of the city where housing conditions are similar or better. In 1927 Annabel M. T.

Murray* studied the growth and nutrition of the slum child in relation to housing, by careful statistical methods, and came to the conclusion that "no consistent evidence is afforded by the present investigation that the weight and height of the children observed under 5 years are related to their inhabiting one or two room houses." On the other hand, "the correlation for weight and height with maternal efficiency shows a closer relationship."

The campaign for better housing facilities therefore should not be based on the premise that bad housing makes for higher tuberculosis morbidity and mortality, for higher infant and general death rates, and for the stunting of child life, but on other grounds, sanitary, moral, and civic, which should be equally potent in stimulating public interest and support. Certain factors relating to housing do exert a direct or indirect effect on health. These items should be emphasized but used only within their limitations.

Housing evils related to health and sanitation. — In order to fully understand the requirements of good housing and its relation to health and sanitation, it is necessary to be familiar with existing housing evils. Among these, the following may be enumerated.

1. Lack of a water supply system delivering pure water in the home.
2. Lack of proper or adequate sewerage facilities.
3. An inadequate or unsatisfactory system of refuse collection and disposal.
4. Infestation of the dwelling with flies, other insects, or rodents.
5. Damp cellar or basement living rooms.
6. Unsatisfactory drainage of rain water and melted snow coming from the roof, which results in the formation of stagnant pools and wet or damp cellars.
7. Dark rooms.
8. Inadequate access to fresh air and sunlight.
9. Overcrowding, including bedroom overcrowding and the lodger evil.
10. Lot overcrowding.
11. The construction of dwellings too close to each other.
12. The construction of dwellings of undue height.
13. Unpaved, filthy alleys.
14. Excessive noise.
15. Obnoxious gases or odors in the atmosphere.
16. Excessive smoke in the atmosphere.
17. Excess fire hazards and inadequate fire protection.

* "The Growth and Nutrition of the Slum Child in Relation to Housing," *Jour. of Hygiene*, v. 26, 1927, pp 198–203.

Old housing evils should be ameliorated and new ones prevented. — There is no apparent reason why those housing evils related to health and sanitation should not be eliminated in time through corrective inspections and education. Certainly in new construction the evils should be avoided through the enforcement of existing or new housing legislation. Where intolerable slum conditions prevail, drastic action on the part of the municipality may be necessary to rectify the situation. The action of Boston in eliminating the North Bennett Street slum hole in the North End, and that of New York in removing the slum dwellings in the Forsythe-Christie Street section of the East Side, are typical illustrations.

Desirable housing conditions for a family of five. — The ideal housing conditions for most families is a single, detached house, surrounded by a plot of ground, providing adequate space for lawns and a small flower and vegetable garden. This would insure plenty of fresh air and sunlight to the occupants, a place for the children to play, and an opportunity for gardening during the spring and summer months. It would also serve to build up family solidarity and to cultivate civic pride and social responsibility. The house for a family of five, consisting of two parents and children of both sexes, should have at least three bedrooms, besides a kitchen, living room, and bathroom, and there should be adequate facilities for heating, lighting, and cooking. The ground should be adequately drained and there should be suitable facilities for water supply, sewerage, and refuse disposal.

Sanitary and hygienic requirements of good housing. Water supply. — A safe and adequate water supply is one of the primary requirements of hygienic living, but it must be convenient if it is to be truly serviceable. Where water must be carried into the dwelling, either from the hall in an apartment, or a hydrant in the street or yard, its value is greatly diminished, for it is difficult, under such conditions, for people to practice personal and domestic cleanliness. Every family should therefore have exclusive access to running water in the house or apartment. Where running water is not available in certain urban districts, such facilities should be provided as promptly as circumstances allow. It is desirable that running hot water, as well as cold, should be available.

Sewerage facilities. — Indoor flush toilets, discharging into sewers, cesspools, or septic tanks are essential housing equipment,

and help to promote good health. Indoor toilets are always convenient and can be kept clean and warm. A washbowl, with running water, should be convenient to the toilet, in order to facilitate proper hand hygiene. Where indoor flush toilets are not available open privies are usually provided. In such cases a fly and odor nuisance, and a potential menace to health may exist. Where privies are in use soil pollution and the subsequent contamination of nearby well water supplies are difficult to avoid. In urban communities every effort should be made to eliminate existing wells and privies as promptly as possible.

In providing plumbing facilities for multiple dwellings the spaces around the pipes passing from one floor to another should be made air-tight. This is necessary to prevent the circulation of unpleasant odors from one apartment to another; to keep out sounds and noises; to check the passage of vermin between apartments; and to diminish the fire hazards by eliminating natural flues.

The use of water or toilet facilities jointly by two or more families should be prohibited. Private facilities should be provided for each family. Outdoor flush toilets should also be prohibited, for they are not convenient and are rarely protected against freezing. As a result, intolerable and even hazardous conditions are sometimes created, which should be avoided. The location of toilets in the halls of apartments or in kitchens and dining rooms should likewise be prohibited.

Every water closet compartment and bathroom should have adequate provision for light and ventilation. To this end, at least one window, adequate in size, which opens directly upon the street, yard, or court should always be available.

Refuse collection and disposal. — Another important sanitary function, for which each community should make adequate provision, is the collection and proper disposal of solid wastes or refuse. Where garbage is allowed to accumulate or is strewn on the ground, flies and rodents are attracted, and noisome odors may be liberated. Where rubbish is allowed to accumulate, a fire hazard is created, and if rubbish is dumped in the back yard or alley, the environment becomes unsightly as well. If the rubbish contains tin cans or empty bottles, rain water is soon collected, and these serve as local breeding places for mosquitoes. The only solution of this vexing problem is for the community to

provide periodic collections of garbage, rubbish, ashes, and other forms of refuse. Such collections must be frequent enough to satisfy the needs of every section of the city. Annual clean-up campaigns may supplement periodic collections of refuse, but they cannot be used as a substitute. Municipal refuse must also be disposed of properly if a general nuisance or menace to health is to be avoided.

Flies, other insects, and rodents. — Every effort should be made to keep flies out of the house and to destroy them after they get in. Exclusion of flies may be accomplished by screening all doors, windows, and other openings to the house or apartment, while destruction is achieved by swatting or poisoning. The best method of combating flies, however, is to eliminate their breeding places. This means the elimination of manure piles and open privies and the prompt removal of accumulations of cut grass, garbage, or other organic refuse.

Mosquitoes also have public health significance in relation to housing. Again, the best way to combat them is by exclusion, destruction, and the elimination of their breeding places. Doors, windows, and all other openings to the house should therefore be thoroughly screened with material having not less than 18 mesh to the inch. All screens should fit properly and effectively and should be in good condition. Stagnant pools and other accumulations of water in the environment should also be eliminated. If the problem is more than a local nuisance it should receive municipal attention.

Rodents may carry plague, and in seaboard communities especially, their elimination or control is particularly desirable. They are also responsible for the destruction of enormous quantities of food, and often aid in infecting such food. To keep them out of the home is a problem of considerable magnitude. Much can be done to minimize their significance, by making each dwelling rat-proof, by storing food in protected containers, and by capturing and destroying rodents by the ordinary household methods as soon as their existence in the house becomes apparent.

Damp cellar and basement living rooms. — It is commonly accepted that dampness is prejudicial to health. Dampness coupled with low temperatures robs the body of its heat, and thus undermines the normal resistance of the individual to colds and other more serious respiratory infections. Living in damp

cellar and basement dwellings should therefore be prohibited. However, if cellar and basement dwellings can be made damp-proof and water-proof, and if they are well lighted and properly ventilated, the objection to their use is removed, and under such conditions occupancy need not be prohibited. But in general, basement and cellar dwellings are not regarded favorably from a public health point of view, and where they are permitted, they should have the sanction of the local health department. Furthermore, in apartment houses and other buildings where heating is not a matter of individual control, heat should be supplied whenever the outdoor temperature, between 7 A.M. and 11 P.M., falls to 50° F., or less. This is essential for maintaining the vital resistance of the occupants.

Unsatisfactory drainage. — The area surrounding each dwelling should be properly graded and drained so that the rain water and melted snow may be removed expeditiously. Where this is not the case, damp or wet cellars and basements result, foundations may be undermined, or stagnant pools of water may be created, which in the summer may serve as breeding places for mosquitoes. In the winter such pools may freeze and thus present a health hazard through accidental falls.

Dark rooms. — Light, sunny rooms are desirable because of the wholesome psychological effect they create. Sunlight also promotes cleanliness, which in turn promotes good health and hygienic habits. Despite the fact that ordinary window glass filters out most of the beneficial ultraviolet rays of sunlight, some undoubtedly pass through, and these have a benign influence. The red rays or heat rays of sunlight pass through glass without interruption, and, since they promote warmth and dryness in the home, are also beneficial.

Accordingly, every room in a dwelling should have at least one window which opens directly on to the street, yard, or court. Such windows should be located so that every portion of the room will be properly lighted on sunny days. In order to insure proper lighting and satisfactory ventilation, the window area in each room should be at least one-seventh of the floor area. Every room, except the bathroom and water closet compartment, should contain at least 90 square feet of floor area, and should not be less than 7 feet wide in any portion. In general, rooms should be at least 9 feet in height, except in private dwellings, where for aes-

thetic reasons, it is desired to have the height of rooms only 8 feet, 6 inches.

Fresh air and ventilation. — Fresh air is essential for robust health, and every dwelling should have access to an abundant supply. During cold weather this is easy to attain, but during hot weather it may be more difficult. The problem of an adequate supply of fresh air is linked up with the height of buildings, the width of streets, the availability of yards and courts, with lot overcrowding, with the distances between adjoining and proximate buildings, with the number and size of windows in each room, and with the presence of obnoxious gases, odors, and smoke in the atmosphere. Air conditioning for homes during hot weather is a likely future development, but because of the expense involved, it is at present applicable only to better homes where housing problems are absent

Every dwelling should have a rear yard extending across the entire width of the lot. The size of the rear yard should depend on the height of the dwelling, and whether it occupies a corner or interior lot. Each yard should be open at every point and should be unobstructed from the ground to the sky. The following table specifies the depth of each yard for dwellings of various heights, when the total depth of each lot is 100 feet.

TABLE 26

DEPTHS OF YARDS ON LOTS 100 FEET DEEP *

HEIGHT OF DWELLING	CORNER LOTS	INTERIOR LOTS
1 story	15 ft.	15 ft.
2 "	15 "	20 "
3 "	15 "	25 "
4 "	20 "	30 "
5 "	25 "	35 "
6 "	30 "	40 "

Where courts are available the size should be proportionate to the height of the dwelling. They should also be open and unobstructed from the ground to the sky. The length of an inner court should not exceed four times its width, and should not be less than twice the minimum width for each dwelling proposed in Table 27 on page 428.

* Lawrence Veiller, *A Model Housing Law*, 1917.

TABLE 27

MINIMUM WIDTH OF INNER COURTS

HEIGHT OF DWELLING	MINIMUM WIDTH OF COURT
1 story	6 ft.
2 "	7 "
3 "	8 "
4 "	9 "
5 "	11 "
For each additional story	Add 2 "

In order to further insure an adequate amount of fresh air and sunlight for dwellings, their height should be limited. This would probably produce no hardship in any city or town in the United States with the possible exception of New York. In general, a dwelling should not exceed in height the width of the widest street on which it abuts, and in no case should it be permitted to exceed 100 feet in total height. This regulation should not apply to hotels. The width of the street should be measured in the shortest straight line from one building line to the other directly opposite.

Overcrowding. — That overcrowding is directly related to health is apparent from the knowledge that disease is transmitted frequently from one person to another by direct contact. Any factor which favors frequent and intimate contact between people favors the dissemination of disease. However, it is difficult to determine the extent to which overcrowding is responsible for disease, for the development of disease is dependent not only on the extent of overcrowding and hence on the opportunities of contact, but likewise on the hygienic practices of people and their vital resistance. Children in congested areas of large cities show a greater proportion of Schick negative tests than do children who live in the finer residential districts or in the suburbs, a fact that illustrates that acute or subacute diphtheria infections occur more frequently in congested areas, which results in a higher proportion of immune children among those who survive. Overcrowding undoubtedly favors the spread of tuberculosis, influenza, pneumonia, colds, diphtheria, scarlet fever, measles, whooping cough, smallpox, and the various other diseases that are spread primarily by contact infection. A family of five, including two parents and three children should occupy at least five rooms, exclusive of the bathroom.

*Lawrence Veiller, *A Model Housing Law*, 1917.

Where overcrowding exists in an apartment or dwelling, bedroom overcrowding is likely to be a concomitant evil. Bedroom overcrowding is undesirable because it favors the spread of venereal and respiratory infections, because it is not conducive to restful sleep, and because it is not in accord with the requirements of decency. Enough bedroom facilities should be available so that not more than two persons should occupy a sleeping room at the same time.

Associated with the problem of overcrowding is the lodger evil. Frequently this condition is found among recent immigrants who because of ignorance, low standards of living, high rents and low income, or greed, take in lodgers to ease the financial strain. This practice, except where favorable conditions prevail, should be combated through education and the cultivation of higher standards of living. The present restriction of immigration doubtless will also aid in the solution of the problem. The construction of suitable dwellings at moderate cost or rental, and the provision of cheap and rapid transportation facilities, will also help in taking people out of congested slum areas where land is expensive and rents correspondingly high. Finally, through sanitary inspections and supervision, the worst phases of the lodger problem can be eliminated or kept under control.

Lot overcrowding. — Wherever lot overcrowding is permitted it is difficult to get suitable natural light and proper ventilation. Lot overcrowding therefore represents an evil of primary significance. It also increases the discomforts of noise by bringing families in opposite dwellings closer together; it diminishes or eliminates the yard area where children may play in safety, and compels them to use the street as a playground; and it increases the possibility of back to back dwellings and the construction of other dwellings that are altogether too close to each other. Various remedies have been suggested for eliminating the evil of lot overcrowding, chief among which has been to restrict the amount of land used for the building in accord with the needs of each situation. But the possible circumstances are so great that one would soon be lost in a maze of detailed requirements for special conditions. In general, however, if it is required that each room, bathroom, water closet, hall, etc., should have one or more windows, and that each window should open on to a street, court, or yard of adequate dimensions in order to provide sufficient light and satisfactory

ventilation in each room, the problem of lot overcrowding would be solved as effectively as possible in this way.

Unpaved, filthy alleys. — There is much to be said in favor of the rear alley. It keeps some of the trucking off the street and thus aids in controlling some of the nuisances due to noise and unsightly conditions in the front or living portion of the house. It permits food and merchandise to be delivered at the rear of the house directly. It also provides a more suitable location for ash cans and rubbish barrels on days when these wastes are collected.

Unfortunately these benefits create objectionable conditions of their own, some of which may be greater than those which they eliminate. The rear alley is an excellent illustration of the statement, "Out of sight, out of mind." Because the alley is at the rear of the house it does not receive the same care and consideration as the front. As a result, the alley often becomes the repository for tin cans, rubbish, garbage, and other wastes, and since alleys are not cleaned frequently these wastes accumulate and become a fire hazard and public nuisance. If the alley is unpaved the situation becomes aggravated, for the noise of passing vehicles is increased, and the nuisances resulting from accumulations of refuse are augmented. In general, therefore, it is wiser not to provide alleys, but those that are available should be paved. The provision of frequent public collections of refuse will also aid in minimizing the nuisances associated with alleys.

Excessive noise. — This subject has been adequately treated in the chapter on Air in Relation to Health and Comfort. Noise is favored by overcrowding for every individual is a potential noise maker. There is sufficient evidence to show that noise interferes with sleep and rest, and thus thwarts the recuperative powers of the body. This undermines resistance and paves the way for disease. Noise makes for irritability; it interferes with physical and mental effort; it affects the appetite unfavorably; it seems to affect hearing; it makes for increased accidents, and has other unfavorable or injurious effects on the body.

Obnoxious gases, odors, and smoke. — These subjects have also received adequate treatment in the chapter on Air in Relation to Health and Comfort. Areas used for residential purposes should be particularly free of the atmospheric pollutions resulting from the discharge of obnoxious or dangerous gases, vile or objection-

able odors, and smoke. This is necessary in order to promote health and comfort.

Fire hazards. — While this subject is definitely related to safety it obviously has certain health aspects. A death resulting from preventable fire is just as significant in the mortality statistics as a death from preventable, communicable disease. From the standpoint of the public health, therefore, houses should preferably be made of fire-resistant materials, especially where three or more families are housed in the same dwelling, and the dwellings are close together or continuous. The roofs of all houses — single and multiple — should always be made of fire-resistant materials. In addition, adequate public hydrants should be available, and there should be sufficient and well-organized fire-fighting personnel and equipment to meet any emergency.

Accidents and accident fatalities in the home. * — The number of accidents that occur in the home and their seriousness are not ordinarily appreciated. In 1931 there were approximately 30,000 deaths and 4,500,000 disabling and serious injuries due to accidents in the home. The deaths due to accidents in the home account for 30 per cent of all the accidental deaths occurring in the United States, and approximate in number the annual fatalities associated with motor vehicles.

Among the persons insured in the Industrial Department of the Metropolitan Life Insurance Company between 1925 and 1930,† home accident fatalities occurred at a rate of 13.3 per 100,000 policyholders. Burns accounted for 27.8 per cent of the fatal home accidents, falls for 30 per cent, and gas poisoning for 14.6 per cent. The death rate from home accidents in 1930 was only 5 per cent less than that for 1925, the reduction being due to fewer deaths from burns, scalds, and illuminating gas. On the other hand, the death rate from falls in 1930 was 40 per cent higher than for 1925. Improvements in heating and cooking devices and greater protection against the hazards of illuminating gas are said to account for the reduction in accidental deaths in the home due to these causes.

Transportation facilities and city planning. — The solution of housing problems will never be achieved without municipal fore-

* *Accidental Facts*, National Safety Council, 1931, p. 7.

† Louis I. Dublin, *Report to the Committee on Housing and Health, President Hoover's Conference on Home Ownership and Home Building*, 1931.

sight and planning. It is always much more difficult to eradicate evils due to the abuse of land and property than it is to prevent them by intelligent planning. Therefore some agency should exist in every community, preferably official in character, which should be responsible for developing a town or city plan, in which the element of housing would receive constant consideration. This would undoubtedly lead to the adoption of a model housing law and zoning ordinance, to the elimination of slum areas and slum conditions, and to the construction of model tenements and other types of model dwellings.

In addition, intelligent planning would provide cheap and satisfactory means of rapid transportation so that large numbers of people could live in sparsely settled areas and still be conveniently near their places of employment. In such areas the single family dwelling should be fostered. With the decentralization of industry in some instances, and the development of small communities, much can also be done to provide suitable housing facilities for the working population in the low income group and at the same time to avoid the evils of overcrowding.

CHAPTER XXIV

NUTRITION AND THE PUBLIC HEALTH

Man's dependence on food. — Life and health are inextricably linked with food. From time immemorial man has struggled to obtain and conserve his food supply in order to insure his ability to survive. At first the chief problem must have been to obtain enough food to satisfy the needs of the body. To this end he fished and hunted. Then came the problem of eliminating the parasites that infested his foods, and this was accomplished primarily by cooking. Conservation by means of cold and drying must also have been employed early in the history of the race. Later, grains and vegetables were introduced; likewise fruits; animals were domesticated and animal milk became an important food. Without a constant food supply of suitable quality, life is jeopardized and the very survival of the individual or the race is threatened.

Under conditions of modern civilization the adequacy of the food supply is no longer a matter of grave concern. The earth is bountiful in its yield of fruits, grains, and vegetables, and modern methods of food preservation and transportation make it possible not only to tide over the lean months of the year with the products of the growing seasons, but surplus foods can be shipped to regions of the earth where foods are not plentiful or where such varieties are not indigent to those areas. In many respects rapid means of transportation coupled with refrigeration have eliminated the seasons almost entirely. Fresh fruits and vegetables are shipped from tropical and subtropical regions to the north at a time when the soil is still bleak or barren. And yet starvation and famine are not unknown even today among the more backward people of the earth. Famine in China is a recurrent phenomenon and starvation in Russia and India have occurred even in recent years. The World War emphasized dramatically the great struggle for food. With millions of men engaged in military pursuits, with ports blockaded, and submarines destroying the ships laden with the necessities of life, the constant daily dependence of man

on a food supply was brought into outstanding relief. As winter approaches and their food supply is cut off, birds migrate. Some animals hibernate throughout the long winter months and live on the surplus energy they have stored in their bodies during the bountiful seasons. But man has built cities, has accumulated property, has developed industrial and professional pursuits in the conviction that with warmth and light, with transportation and science, he will be able to survive successfully, and even comfortably, the rigors of a long and barren winter season. It is an accomplishment worthy of his superior mentality and of his remarkable powers of adaptation.

The twentieth century revolution in nutritional knowledge and practice. — The progress made in the science of nutrition since the beginning of the twentieth century is one of the outstanding achievements of the present era. Were it not associated with so many other scientific accomplishments of equal or greater magnitude, its value might be more fully appreciated. We take for granted the significant scientific contributions which are woven almost imperceptibly and unconsciously into our daily lives, little realizing what they mean to us in increased health, comfort, and longevity, and forgetting almost completely the less favorable conditions under which our recent ancestors lived and struggled. The establishment of the germ theory of disease during the last quarter of the nineteenth century, and the demonstration that infected water, milk, and food are often vehicles of disease and death, overshadowed in importance the need for research on the significant problem — what constitutes an adequate and satisfactory diet. Man had lived on the earth not for centuries, but for millions of years, and his chief interest as far as food was concerned was to satisfy his need for quantity. The fact that the lack of certain elements in the diet might make for stunted growth, for eye diseases, for limited longevity, for diseases like beriberi, scurvy, rickets, pellagra, goiter, and anemia was practically not appreciated. And yet there is hardly a school child today who does not learn about vitamins and mineral salts, about the "building stones" that make for good, healthy human tissue and about the importance of milk, fruits, and vegetables in the daily diet. The newspapers often review the most recent contributions in the field of nutrition; the clinic and the public health nurse assist in the dissemination of such information; and the physician in his

daily round does his share in spreading the knowledge of the essentials of sound nutrition. Campaigns to drink a quart of milk per day, to use orange juice and tomato juice in the daily diet, to eat vitamin bread and yeast for health, to use cod liver oil, halibut oil, or viosterol, to eat carrots, spinach, lettuce, and other vegetables, are but a few of the evidences of the mass propaganda of recent years. And it has been remarkably successful, for the dietary of the American people has undergone a profound change during the past twenty years.

Once it was demonstrated that disease in the human body is the result not only of pathogenic bacteria and other parasites but likewise of derangements in the diet, a flood of scientific investigation was released which has resulted in much of our present nutritional knowledge. The progress in nutrition has been so steady and far-reaching, that any account of it, especially in a work of this sort, must be inadequate and fragmentary. Nevertheless, it is important to present the salient features of the newer knowledge of nutrition, for on them depend the resistance of the individual to infection and disease, his health and stamina, his ability to preserve the characteristics of youth and even his longevity.

Factors affecting progress in nutrition. — Progress in nutritional knowledge was retarded for two reasons primarily: first, because of the overshadowing importance of the germ theory of disease; and second, because the sciences of physics and chemistry were not yet sufficiently developed to detect the presence of the minute amounts of elements in foods which were of such great importance to man. The fact that the human body was a mechanism with a daily intake and output of energy, of food and waste products, was appreciated, and the fuel value of foods, measured in terms of calories, had become part of our general information. These could be determined by the chemical and physical methods of analysis already available. But the significance of vitamins, mineral salts, and of specific amino acids had to await the development of a new scientific tool. This was provided in the form of the white rat and guinea pig, two laboratory animals, with a life span much shorter than that of man, which could be supplied foods carefully regulated and controlled in amount and quality, and the effects of such dietaries scientifically observed. By assuming that the nutrition of these lab-

oratory animals obeys the same requirements as that of the animal, man, a great deal of valuable information has been accumulated which has placed the nutrition of man on a sounder and more scientific basis. That such an assumption is warranted has been demonstrated not only in the improvement of human health and vigor when the diet was modified in accord with the newer knowledge of nutrition, but likewise by the conquest of such diseases as beriberi, scurvy, pellagra, rickets, goiter, and anemia. In recent years, the effects of restricted diets in war-ridden countries and in famine areas has confirmed for man the experimental evidence gleaned in laboratories all over the world, where the test animals were the white rat and the guinea pig.

Essential elements in animal nutrition. — The food supply of man which must be suitable in quantity and quality to yield sufficient energy, to build tissue and to regulate the body processes, is divided into proteins, carbohydrates, fats, mineral salts, vitamins, and water. The importance of water to the animal organism and in fact to all forms of life has been adequately discussed in a previous chapter. Here it is only necessary to describe the significance and the rôle of the other elements in animal nutrition.

Proteins. — All living things, regardless of size or complexity, contain protein. Chemically, proteins contain carbon, hydrogen, oxygen, and nitrogen. Usually also, they contain sulphur. Frequently, phosphorus and other chemical elements are present. The animal organism, unlike plants, is unable to manufacture its protein supply from simple, inorganic substances. Animals are therefore fundamentally dependent on plants for existence and survival, and since the plant builds up its carbohydrate and protein supply by utilizing the sun's energy through the agency of chlorophyll, all life on the earth is fundamentally dependent on the sun. Man is dependent for his protein supply either on plant or animal proteins. These are broken down in the body into amino acids — their cleavage products — and resynthesized into human tissue or human protein. Muscle tissue, for example, is composed of protein to a large extent, and since such tissue is constantly being used up and broken down proteins are indispensable in animal nutrition either for growth or repair or both.

The remarkable achievements that have crowned nutritional research during the past twenty-five years, first in the discovery

of vitamins and more recently in the significance of minerals in animal nutrition, have overshadowed in importance the value of proteins, carbohydrates, and fats. It must be emphasized, therefore, that the energy yielding foods like carbohydrates and fats are also important, and that the use of protein in suitable forms is absolutely indispensable.

Amino acids. — Since all proteins are resolved in the animal body into amino acids, it is important to know those that have been determined and whether all are necessary to the same degree for satisfactory nutrition. To date, twenty-one amino acids have been identified, the result of many analyses of numerous and varied proteins found in nature. The complete list follows.

TABLE 28

KNOWN AMINO ACIDS

1. Alanine	11. Leucine
2. Arginine	12. Lysine
3. Aspartic acid	13. Methionine
4. Cystine	14. Norleucine
5. Glutamic acid	15. Ornithine
6. Glycine	16. Phenylalanine
7. Histidine	17. Proline
8. Hydroxy-glutamic acid	18. Serine
9. Hydroxy-proline	19. Tryptophane
10. Isoleucine	20. Tyrosine
21. Valine	

Of these amino acids, at least four — cystine, histidine, lysine, and tryptophane — are essential for maintenance and growth. Without them satisfactory animal nutrition cannot take place. Proteins vary considerably in their completeness of amino acids necessary for normal nutrition. Certain proteins like casein and lactalbumin of milk; ovalbumin and ovovitellin of egg; glycinin of the soya bean; excelsin of the Brazil nut; and edestin, glutenin, and maize glutelin of the cereal grains are complete. On the other hand some proteins like gliadin of wheat, hordein of barley, and prolamin of rye maintain life but do not support growth, even when fed in adequate amounts. Such proteins are partially incomplete, for they lack the amino acids essential for growth in the animal organism. Finally, there are proteins like zein of corn and gelatin which are unable to maintain life or to support growth when they are the sole proteins in the diet. Such proteins

are also devoid of essential amino acids and are known as incomplete proteins.

The following table records the approximate amino acid content of one complete protein, one partially incomplete, and two totally incomplete. By observing their deficiencies and recalling the requirements of proteins for satisfactory animal nutrition the reasons for their adequacy or lack of it when each represents the sole source of protein in the diet will be apparent. The fact that the total of each analysis does not add up to 100 per cent is accounted for by unrecognized losses or gains experienced in the examinations.

TABLE 29

PERCENTAGE COMPOSITION OF AMINO ACIDS IN FOUR PROTEINS *

AMINO ACID	CASEIN	GLIADIN (WHEAT)	GELATIN	ZEIN (MAIZE)
Alanine	1.85	2.00	8.70	9.8
Arginine	3.81	3.14	8.2	1.8
Aspartic acid	4.10	0.8	3.4	1.8
Cystine	*0.94*	*2.32*	*0.3*	*1.03*
Glutamic acid	21.77	43.66	5.80	31.3
Glycine	0.45	0.00	25.50	0.00
Histidine	*2.84*	*3.35*	*0.90*	*0.8*
Hydroxy-glutamic acid	10.50	2.40	0.00	2.5
Hydroxy-proline	0.23	?	14.10	0.00
Isoleucine	—	—	0.00	0.00
Leucine	9.70	6.62	7.10	25.0
Lysine	*7.62*	*0.92*	*5.9*	*0.00*
Phenylalanine	3.88	2.35	1.40	7.6
Proline	7.63	13.22	9.50	9.0
Serine	0.50	0.13	0.40	1.0
Tryptophane	*2.20*	*1.14*	*0.00*	*0.00*
Tyrosine	6.50	3.50	0.01	5.88
Valine	7.93	3.34	1.00	1.9
Ammonia	1.61	5.22	0.4	3.6
Summation	94.06	94.11	92.61	103.01

Casein is a complete protein, gliadin, partially incomplete, and gelatin and zein, incomplete.

The fuel requirements of the body. — Prior to the establishment of the importance of vitamins and minerals in sound animal nutrition, the satisfactory quality of a diet was measured in terms of its fuel value. To a great extent this aspect of nutrition has been

* From H. C. Sherman, *Chemistry of Food and Nutrition*, Fourth edition, 1932, The Macmillan Company, p. 48.

submerged in recent years under the flood of information that has come from numerous laboratories concerning vitamins and minerals. Since the body is a living machine and uses up energy even when at rest, it is obvious that this energy loss must be replaced if the body is to enjoy good health and vigor, and continue to perform work. Hence the fuel value of food is an item in nutrition which cannot be ignored. It must be regarded as equal in importance to vitamins and minerals if the entire welfare of the organism is considered.

The fuel value of foods is measured in terms of the heat energy they are able to supply. The unit employed is the large Calorie and not the small caloric commonly used in physical measurements. The Calorie is defined as the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade. This is almost the equivalent of the amount of heat required to raise the temperature of four pounds of water one degree Fahrenheit. A small calorie is defined as the amount of heat required to raise the temperature of one gram of water one degree Centigrade. The large Caloric therefore is a thousand times as large as the small calorie.

The energy needs of the body depend on many factors, among which may be mentioned the amount of muscular work performed; whether or not the body is at rest; the heat loss to the environment by radiation, which is affected by clothing, wind action, relative humidity, and atmospheric temperature; the age of the individual, his size, and weight, and the state of his health. Sedentary workers, for example, require less energy in the form of food than do athletes, ditch diggers, farm laborers, fishermen, or lumbermen. The energy requirements of the sedentary adult worker may vary from about 2,000 to 2,400 Calories per day, while the lumberman may require over 5,000 Calories per day to satisfy his needs. Absolute rest in bed will diminish the energy needs of the body below the amount required to satisfy the sedentary worker. The wise man who has attained his full growth and maturity will regulate his energy intake to meet the needs of his occupation. This individual adjustment is essential both to good health and longevity. A superabundance of energy producing food in the diet of the full grown individual leads to obesity, and studies made by life insurance companies in America indicate that the expectancy of life for obese individuals past the age of 30 is considerably less than for those who

are either normal in weight for height and age, or even slightly under normal weight. On the other hand, prior to age 30, the life expectancy of individuals slightly overweight is better than for those who are underweight. After age 30, the life expectancy of the individual varies inversely with the degree of overweight.

The fuel foods. — The fuel needs of the body are derived from carbohydrates, fats, and proteins. Carbohydrates are foods containing carbon, hydrogen, and oxygen in which the atomic relationship of hydrogen to oxygen is the same as that found in water, *i.e.*, two to one. Fats are also composed of carbon, hydrogen, and oxygen, but they contain less oxygen and more carbon and hydrogen than the carbohydrates. Since the energy of foods is obtained by oxidation, the fact that fats contain less oxygen and more carbon and hydrogen than the carbohydrates make them more concentrated forms of fuel. For the same reason the body stores its excess energy derived from foods in the form of body fat.

The carbohydrates. — The sugars and starches are excellent illustrations of carbohydrates, and any food that contains sugar or starch is a source of carbohydrate material. Sugars and starches are synthesized by plants from such simple inorganic substances as carbon dioxide and water, and they represent the most abundant sources of energy utilized by man. The carbohydrates are divided into various groups depending on their molecular composition. There are, for example, the monosaccharides, which include dextrose, fructose, and galactose; the disaccharides, which include sucrose, lactose, and maltose; and the polysaccharides, which include starch, glycogen, and the dextrins.

Sucrose is broken down in the animal body to form dextrose (glucose) and fructose. Both are used to produce glycogen which is stored in the liver, and eventually is utilized by the cells as a source of energy, but not until the glycogen is converted once more into glucose. Lactose, which is the sugar found in milk, is broken down in the body to produce glucose and galactose, both of which may be stored in the liver as glycogen. Similarly, maltose is converted to glucose and again the glycogen content of the liver is enriched.

It is obvious, therefore, that in the assimilation of the disaccharides it is necessary to transform them first into monosaccharides, after which they are changed and stored in the liver in the form of glycogen or animal starch. It also illustrates the fate of

monosaccharides themselves — taken directly into the body. The assimilation of starch is somewhat complex, but the end result is similar to the disaccharides. Starch is first broken down into dextrin and this in turn into maltose, which is then converted into glucose and finally into glycogen. Since the blood is the vehicle for the transfer of cellular food and the removal of waste products, it is not surprising to find it constantly carrying glucose to and from the liver and to the cells. In fact, by careful autonomic regulation, the glucose content of the blood is kept constant.

The sources of carbohydrates are numerous and varied. Glucose is found in grapes, fruits, plant juices, sweet corn, onions, and unripe potatoes. Fructose or fruit sugar is found in fruits, honey, and plant juices. Galactose results from the breaking down of milk sugar and is not found naturally as such. Sucrose is found abundantly in sugar cane and sugar beets and is commonly used as table sugar. It is also found in fruits and plant juices, in the sugar maple, in pineapples, and carrots. Lactose is found in milk and maltose is produced from starch. Starches are found in seeds, tubers, bulbs, unripe apples and bananas, and in the stems and leaves of plants. Cereal grains and potatoes are among the richest sources of starch used by man.

Fats and lipoids. — Fats are also widely distributed in nature, and are found both in plants and animals. In plants they are present particularly in the ripe seed. In addition to serving as a concentrated form of fuel, fat in the animal body serves as a protection against mechanical injury as an insulating agent against the rapid loss of heat and as a protection and support for the visceral organs. Animal fat may be formed from carbohydrates, fats, or proteins.

In addition to the true fats, there are fat-like substances called lipoids which play an important rôle in animal nutrition. Lipoids seem to be present in all living cells. Among the prominent lipoids are the phospholipids and the sterols. The brain, for example, contains the highest proportion of phospholipid and cholesterol found in the body. Cholesterol also occurs in nearly all living tissues. Ergosterol is also found in the skin, and when irradiated with ultraviolet light, is converted into the anti-rachitic vitamin.

Protein requirements. — The amount of carbohydrate and fat which should be included in the diet varies with the fuel needs of the body. In general, the human organism requires less protein

than it is wont to have. One of the outstanding changes in human nutrition resulting from the newer knowledge has been the marked curtailment in consumption of protein foods. Experiments have shown that the protein requirements for a man of average weight, *i.e.*, 154 pounds, varies between 21 and 65 grams per day, and averages 44.4 grams. The consumption of excess protein is rapidly eliminated from the body, or is transformed into carbohydrates and fats and utilized as energy. On the other hand, the consumption of excess amounts of fats and carbohydrates results in the accumulation and storage of excess fatty tissue. While the protein allowance in the daily diet should be in excess of the minimum requirements in order to promote good health and stamina, it should not represent more than 10 to 15 per cent of the calorific intake for children and adults up to middle life. For older people, it is wiser to curtail the use of protein foods, first because proteins are not metabolized so readily, and second, because protein consumption favors intestinal putrefaction. The protein intake, however, at all ages should favor the use of complete proteins such as casein. Carbohydrate foods exert a sparing effect on the use of proteins, and the incorporation of lactose in the diet favors the development of non-putrefactive bacteria in the intestine and hence tends to prevent putrefaction. This is another reason why each individual should include a liberal amount of milk in the daily diet.

The mineral elements in nutrition. — Although the existence of certain mineral elements in the human body and in human foods has been known for some time, our knowledge concerning their prevalence and significance has been exceedingly limited. This is partly due to the fact that they are often present only in traces, and could not be identified by the chemical methods of analysis then available. In 1918, however, Osborne and Mendel of Yale University, called attention to our meager knowledge of the trace elements in animal nutrition, and since remarkable discoveries had already been made in the field of vitamin research, it is not surprising that a wave of investigation was inaugurated in this sphere of nutrition which has continued to the present time. In the meantime, methods of chemical analysis were improved, and more important still, a new scientific tool, the spectrograph, was employed and found to be of great value.

At the beginning of the twentieth century it was known that such mineral elements as calcium and phosphorus occurred in the

bones; that iron was associated with the hemoglobin of the blood; that sodium chloride or common salt was necessary; and that potassium, magnesium, and silicon were also present in the body. Furthermore, in 1895, Baumann had shown that iodine was a regular constituent of the thyroid gland. In the past fifteen years, however, our knowledge concerning the existence and significance of the trace elements in the human body has been greatly extended. This had been accomplished by spectrographic examinations of the constituents in the ash of the various organs of the body. Simultaneously various foods were examined for trace elements, and by experimentation their significance in animal and plant nutrition have been determined.

In addition to the elements universally recognized as constituents of protoplasm, namely, carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, sodium, potassium, magnesium, calcium, chlorine, and iron, recent research has disclosed the presence of chromium, copper, and tin in practically all human organs. Silver and aluminum are somewhat less distributed. Cobalt and nickel were found in the pancreas but not in the liver. Titanium was found primarily in the lungs; zinc, especially in the generative organs, thyroid, liver, and kidney; tin in the suprarenal glands; and all of these elements were found in the blood. Rubidium is almost as widely distributed as copper in the body and occurs in greatest concentration in the heart and in striated muscle tissue.

In examinations of various milks for the existence of "biologically rare elements," traces of barium, boron, copper, iron, lithium, rubidium, strontium, titanium, vanadium, and zinc have been found. Furthermore, in attempts to show the importance of trace elements to plant growth, boron, zinc, and manganese have proved to be essential to the growth of maize. Without zinc, wheat and barley die in the early stages of growth, and similarly buckwheat, sunflowers, broad beans, and red kidney beans never come to full maturity or produce seed.

The skeptical will naturally wonder whether the presence of traces of the biologically rare elements in the body and in food is not due to unavoidable contaminations in food preparation rather than because of their physiological significance. The answer will have to await further research in animal and plant nutrition. The evidence is quite clear, however, that in the case of simple goiter, anemia, rickets, mottled teeth, and the vitamin deficiency diseases,

the presence or absence of traces of certain elements plays a significant rôle in the normal functioning of the animal organism. It is therefore necessary to maintain an open mind on the significance of those trace elements which has not yet been established.

TABLE 30

COMPOSITION OF THE HUMAN BODY IN TERMS OF CHEMICAL ELEMENTS

Element	Approximate Amount in Per Cent
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3.0
Calcium	1.5
Phosphorus	1.0
Potassium	0.35
Sulphur	0.25
Sodium	0.15
Chlorine	0.15
Magnesium	0.05
Iron	0.004
Iodine	0.00004
Copper, Manganese, Zinc, Fluorine, Silicon, Other elements	very minute amounts

Functions of the mineral elements. — Although our knowledge of the significance of the mineral elements in the body is still incomplete, some information is already available concerning the rôle which some of them play in the normal or abnormal functioning of the organism. For example, calcium and phosphorus are essential for the formation of bones and teeth, for the rigidity of the skeletal tissues on which the softer organs are suspended, and for the prevention of rickets. Calcium is also necessary for the coagulation of the blood, for the regulation of the action of the heart muscle, and as an ingredient of the soft body tissues and body fluids. Iron is an essential part of the blood, being found in the hemoglobin of the red blood corpuscles which play such an important rôle in carrying oxygen to the tissues and removing the carbon dioxide. Although the blood represents only 7 per cent of the body by weight, it contains 70 per cent of the total iron in the body. In addition to serving as an essential element in animal respiration,

iron or the lack of it has been associated with various anemias. Iron is also present in the chromatin material of all cells. Copper, too, plays a rôle in animal respiration and supplements iron in combating nutritional anemia. The small amount of iodine in the body — one part in 3,000,000 by weight — regulates the metabolism, and a shortage even of this trace quantity leads to simple goiter. Recent work has also shown that the presence of 2 parts per million or more of fluorine in a water supply is responsible for mottled enamel of the teeth, although minute amounts of fluorine and silicon are normally found in the skeletal tissues.

In addition to this incomplete list of certain specific functions which mineral substances perform in the animal body, there are others which are less direct but nevertheless very significant. Mineral matter, for example, enters into the composition of soft tissues such as muscles and blood cells, and in the form of salts it regulates the reaction of the blood and the other body fluids, the osmotic pressure of the body fluids and the body tissues, the reaction of the digestive juices, and the elasticity and irritability of muscle and nerve tissues. The significance of this can be observed from the fact that the reaction of the blood is normally slightly alkaline, the reaction being quite constant, between pH 7.35 and pH 7.43. Slight variations on either side of these limits are not conducive either to life or health. It is a remarkable illustration of delicate biological adjustment and adaptation. This is true despite the fact that the blood carries all the carbon dioxide from the tissues to the lungs for final elimination. The fixed acids of the body are transformed into salts and eliminated through the kidneys. The consumption of meats, fish, shellfish, and eggs results in the production of acid-forming elements in the body, while the consumption of fruits, vegetables, and milk results in base-forming elements.

The importance of mineral salts in the diet is further illustrated by the experiences of miners, steel mill operatives, and others who work under high temperatures. The profuse sweating that occurs under such conditions results in an abnormal loss of salts, and if this is not made up in the drinking water, fatigue and exhaustion take place quite rapidly. The consumption of adequate amounts of beer or drinking water containing 0.2 per cent of sodium chloride satisfies the body loss of salts and brings great relief to the workers. The normal amount of mineral salts excreted daily from the body varies between 20 and 30 grams, in the form of chlorides, sulphates,

and phosphates of sodium, potassium, magnesium, and calcium and as ammoniacal salts resulting from protein metabolism. These salts must of course be replaced in the daily food supply, but in the growing individual there must be an excess intake of mineral matter over outgo, to provide for growth and development. Ordinarily the daily diet provides more than an ample supply of sodium, potassium, and magnesium salts. With calcium salts such is not the case, and it is essential to satisfy the needs of the body for this important mineral substance.

The calcium and phosphorus needs of the body. — The significance of calcium and phosphorus in animal nutrition has been described to some extent in earlier portions of this chapter. It is estimated that 99 per cent of the calcium in the body and 70 per cent of the phosphorus are found in the bones and teeth. Approximately 85 per cent of the mineral matter in the bones and 75 per cent of the entire ash of the body are composed of calcium phosphate. The bones contain calcium not only in the form of calcium phosphate but also as crystals containing calcium carbonate. Phosphates are also utilized in maintaining the acid-base balance of the blood and in the synthesis of certain important cell constituents such as phospholipids and nucleoproteins. Phosphorus is also present in the muscles, the nerves, and the brain. It will be recalled that calcium is also present in the soft tissues of the body and in the body fluids.

Because of the extent to which calcium and phosphorus occur in the human body and the significant functions they perform, it is essential to insure their presence in adequate amounts and in available form in the daily food supply. This is particularly important for growing children, and for pregnant and lactating women, as the embryo and nursing infant must satisfy their calcium and phosphorus requirements from the mother. Since the bony structure of the body contains the bulk of the calcium and phosphorus, and since rickets is due to a deficiency of these elements or their inadequate absorption, it is not surprising that much of the work dealing with calcium and phosphorus metabolism has been related to rickets. This is particularly true since vitamin research demonstrated that vitamin D — the anti-rachitic vitamin — is essential for the proper assimilation of calcium and phosphorus. While definite evidence is not yet available, it is likely that a similar assimilation of calcium and phosphorus is involved in the prevention of dental caries.

Recent experiments have shown that growing children between the ages of 3 and 13 require an average intake of not less than one gram of calcium per day, an amount twice as great as that required for maintenance in the average adult male. The phosphorus requirement for children of the same age group varies from 1.16 to 1.46 grams per child per day, while for adult males of average weight, *i.e.*, 154 pounds, the average requirement is 0.88 grams per day. The evidence also indicates that calcium obtained from milk is assimilated more readily than that obtained from vegetables such as carrots and spinach. Milk contains somewhat more than a gram of calcium per liter — approximately one quart. It is therefore not surprising, in view of the above facts, that experts in nutrition insist that the daily diet of the growing child should contain from three-fourths to one quart of milk, and that the adult should use at least a pint of milk in some form per day. Although the calcium found in lettuce is apparently assimilated even more readily than the calcium in milk, the daily consumption of a peck of lettuce would be equivalent only to a little more than half a pint of milk, as far as the calcium yield is concerned.

The following table enumerates the foods especially rich in calcium and phosphorus, and since American and European dietaries are apt to be more deficient in calcium than any other mineral element, the information takes on added significance.

TABLE 31

FOODS RICH IN CALCIUM AND PHOSPHORUS ARRANGED ACCORDING TO AMOUNT PRESENT

FOODS CONTAINING CALCIUM	FOODS CONTAINING PHOSPHORUS
1. Cheese	1. Cheese
2. Almonds	2. Egg yolk
3. Dried beans	3. Dried beans
4. Egg yolk	4. Almonds
5. Milk	5. Whole wheat
6. Walnuts	6. Peanuts
7. Peanuts	7. Oatmeal
8. Oatmeal	8. Walnuts
9. Eggs	9. Lean beef
10. Turnips	10. Eggs
11. Carrots	11. Dried prunes
12. Dried prunes	12. Polished rice
13. Oranges	13. Milk
14. Whole wheat	14. White flour

The iron and copper needs of the body. — The significance of iron and copper in the human body has been indicated already in a previous section of this chapter. In considering the relative importance of these two elements in foods, particular heed must be given to the iron content of foods, since copper enters as a frequent contaminant of human foods and drink and is present in sufficient amounts to satisfy the needs of the body. Apparently, too, it makes little difference whether the iron is present as organic or inorganic iron, although it is true that iron in certain foods is assimilated more readily than in others. Although milk is deficient in iron, its iron content is assimilated more readily than the iron found in lean beef or wheat.

The amount of iron found in the human body is exceedingly small, about 3 grams by weight or approximately one-tenth of an ounce. Actually its concentration in a full grown individual is about 1 part in 25,000 by weight. It is very significant, however, and lends weight to the importance of the trace elements in satisfactory animal nutrition. It is estimated that a daily intake of 15 milligrams of iron in the form of food will satisfy the needs of the average adult male. Since women demand more iron because of menstruation, pregnancy, and lactation, their food should provide for the extra requirement. The additional demand for pregnancy and lactation alone is at least 3 milligrams per day.

The following table enumerates some of the foods especially rich in iron. The most important sources of iron in the diet should be the fruits and leafy vegetables.

TABLE 32

FOODS RICH IN IRON ARRANGED ACCORDING TO AMOUNT PRESENT

1. Liver	11. Spinach
2. Egg yolk	12. Cheese
3. Dried beans	13. White flour
4. Dried peas	14. Fresh string beans
5. Whole wheat	15. Potatoes
6. Oatmeal	16. Beets
7. Eggs	17. Carrots
8. Lean beef	18. Bananas
9. Dried prunes	19. Oranges
10. Kale	20. Tomatoes

The iodine needs of the body. — Although the iodine content of the body is exceedingly small, representing, by weight, only one

part in 3,000,000 its significance is great. Most of the iodine in the body is stored in the thyroid gland, located in the neck, where it is utilized in the preparation of thyroxine, which regulates the body metabolism. A deficiency in iodine leads to a swelling in the neck, characteristic of simple goiter. Simple goiter is very prevalent in the United States, particularly around the Great Lakes, in the middle west, and in the Pacific northwest. In these regions the water and soil are both deficient in iodine. Preventive measures have been taken in some places by adding sodium iodide to the public water supply for two weeks in the spring and fall of the year, or by giving children chocolate coated sodium iodide tablets during similar brief intervals. Iodized salt has also been employed as a prophylactic against simple goiter in the United States and Europe. People living near the seacoast, near the great natural reservoirs of iodine, *i.e.*, the oceans, have been free of simple goiter. Extensive observations have shown that adolescent and pregnant females are much more susceptible to simple goiter than males in the same age groups. It is therefore important to include iodine-containing foods in the diet or to depend on the prophylactic measures already described.

The following foods are comparatively rich in iodine. In the non-goiterous regions, they include salmon and other seafoods, carrots, oats, and barley; while in the goiterous regions they include butter, loganberries, cherries, string beans, spinach, bran, peaches, pears, and skimmed milk. Cod liver oil is also rich in iodine, and nuts and vegetable oils are likewise good sources of this element.

The vitamins. Historical review. — Since the beginning of the twentieth century a voluminous literature has developed on vitamins, and it would be impossible in a work of this sort to include even a comprehensive review of our present day knowledge. Nevertheless the subject has become such a vital factor in the current interpretation of the requirements of an adequate and satisfactory diet, and has been exploited to such a degree in the scientific and lay press, that it is essential to review at least certain of the salient facts concerning the value and function of these food accessory elements in the human diet.

Knowledge that certain human diseases were due to deficiencies in the diet was current long before the epoch-making discoveries of the twentieth century. As early as 1800, for example, the British

Navy appreciated the value of lime juice as a preventive against scurvy, and between 1878 and 1883, Takaki, a medical officer in the Japanese Navy, demonstrated that beriberi could be eliminated among Japanese sailors by diminishing the quota of polished rice in the diet, by increasing the amount of barley, and by adding meat, condensed milk, and vegetables.

Perhaps the first suggestion that diets composed of protein, fat, carbohydrate, mineral salts, and water are not adequate for satisfactory animal nutrition came from Lunin in 1881 who was investigating the significance of mineral salts in animal nutrition and who found that mice did not thrive on purified diets containing all the elements supposedly essential for satisfactory nutrition, but that they flourished when milk was added. In 1892 Bunge emphasized the necessity of further research into the requirements of an adequate and satisfactory diet, and in 1897, Eijkman, a Dutch physician working in the East Indies, made certain notable observations on beriberi in man and a similar disease, polyneuritis in fowls, which Casimir Funk in 1911 brought more forcibly to the attention of the civilized world. After that the floodgates of vitamin research were let loose and in the brief span of 20 years so much information has been assembled on the nature and function of vitamins that it would not be surprising if the chemical structure and synthesis of the six vitamins known today were definitely established in the near future.

In 1897 Eijkman demonstrated experimentally that polyneuritis in fowls could be induced by restricting their diet to polished rice exclusively, and that the disease could be cured by substituting unpolished rice. He also had an opportunity to study the prevalence of beriberi in relation to diet among approximately 280,000 prisoners in the jails of the Dutch East Indies, and found that for each 10,000 of the prison population there was one case of beriberi among those eating unpolished rice; 416 among those whose diet consisted of a mixture of polished and unpolished rice; and 3,900 among those who subsisted on polished rice alone.

In the meantime American and British workers in the Philippines and the Malay States respectively, working on beriberi, advanced evidence to support the theory that beriberi was a deficiency disease and was not due to a communicable infection as some believed. In 1907 Braddon observed in the Malay States that natives who parboiled the rice before removing the pericarp

or outer covering did not suffer from beriberi. Since the anti-beriberi vitamin is soluble in water this observation was sound and significant. Grijns, in 1901 and 1909, showed that foodstuffs other than unpolished rice could prevent polyneuritis, and presented additional evidence to support the thesis that beriberi was a deficiency disease. He also showed that the anti-neuritic element in certain foods could be destroyed by heating to 120° C.

In 1911, Casimir Funk, working at the Lister Institute in London, repeated the experiments of Eijkman and Grijns, substantiated their findings, and attempted to establish the chemical identity of the protective substance. Believing this substance to contain nitrogen and that it was essential to life, he coined the word "vitamine" in 1912, to include all food accessory substances essential for a complete and satisfactory diet. By 1920 it became evident that there were at least several food accessory substances and that not all of them contained nitrogen, so that the term "vitamine" was a misnomer. But the term had already achieved a prominent place in the vocabularies of the civilized world, and it was impossible to drop it altogether. Accordingly, Drummond suggested dropping the "e" of "vitamine," and using the term "vitamin" to refer to the various food accessory substances, and this is the term in common use today. Further references to important historical work on the vitamins will be made as each is discussed. Suffice it to say here that much of the more recent research in nutrition has been conducted by American and British workers primarily, and that at the present time there is definite information concerning six vitamins. The Americans have named them A, B, C, D, E, F, and G, but since vitamin B is a complex containing F and G, the British prefer to think of vitamin B as being composed of vitamins B_1 and B_2 respectively. Vitamin B_1 is synonymous with vitamin B or F in the American nomenclature, and vitamin B_2 with vitamin G.

Vitamin A. — This vitamin, known also as the growth-promoting and anti-infective vitamin, was discovered almost simultaneously and independently in 1913 by Osborne and Mendel of Yale University and by McCollum and Davis of the University of Wisconsin. They showed experimentally that young animals fed on food mixtures alike in all other respects would continue to grow and thrive when the fat in these mixtures was butterfat, cod liver oil, or egg yolk, or would soon cease growing and shortly

thereafter sicken and die if the fat in their diet consisted wholly of lard. Evidently there was something in butterfat other than its calorific value which made growth and normal development possible, which permitted normal reproduction and lactation, and which was essential to health. This fat-soluble substance was called vitamin A. The lack of it in animal nutrition not only stunts growth and prevents normal reproduction and lactation, but produces an eye disease, a conjunctivitis known as xerophthalmia, which may result in blindness. This disease has been observed, not only among experimental animals, but also among humans — children and adults — in southeastern Europe and in the Orient — who have had to live on restricted diets. Subsequent observations have demonstrated that the lack of vitamin A in the diet, or its serious deficiency, increases the susceptibility of animals to respiratory diseases, to disease of the skin, to eye and ear infections, to infections of the alimentary tract, and to renal calculi. The resistance of the organism to bacterial invasion is apparently intimately related to the storage of vitamin A in the body. Furthermore, in 1925, Sherman and MacLeod demonstrated that animals kept on a liberal allowance of fat soluble A with the diet adequate in all other respects lived twice as long as similar animals kept on the same diet but with the vitamin A allowance greatly restricted. Vitamin A is therefore apparently related to longevity and is essential not only in the life of the growing child but also in the adult.

Vitamin A is found abundantly in butterfat, egg yolk, and cod liver oil. The first two foods are products of animal origin. Since animals are fundamentally dependent on plants for food, it is not surprising that the green and yellow vegetables are also excellent sources of vitamin A. Recent work has shown that carotene, one of the pigments in yellow corn, sweet potato, and carrots, is in reality the precursor of vitamin A in the animal body. When carotene is taken into the body, it is stored, transformed, and delivered to other parts of the body by the liver, so that liver too becomes an excellent source of vitamin A. The amount of carotene necessary to promote growth is incredibly small, since only 0.000005 gram is required in a small animal weighing 100 grams that has been deprived of vitamin A. This represents a concentration of only one part of carotene in twenty million parts of body substance. However, if a high degree of health and vigor is to be maintained and if longevity is to be

fostered, then vitamin A or its precursor, carotene, must be supplied in more liberal amounts.

Fish liver oils such as cod liver oil and halibut oil (haliver oil) are rich sources of vitamin A. Since these fish do not consume green vegetables or animal foods like butter and eggs, the source of their vitamin A becomes a matter of considerable interest. It has been shown that green water plants like the diatoms and algae can synthesize a substance known as provitamin A. These plants are eaten by crustacea and these in turn become the food supply of small fish. The larger fish, like the cod and the halibut, feed on smaller fish and thus come into possession of the vitamin A which was formed originally by the green water plants. As the liver is the great storehouse for vitamin A in fish as well as in animals, the oil obtained from fish livers is rich in this important vitamin.

Although the table at the end of this chapter shows the distribution of the various vitamins in the important foods of man, it is desirable to enumerate briefly at this point those foods which are good sources of vitamin A. Mention has been made already of the value of butter, egg yolk, cod liver oil, and haliver oil as sources of vitamin A. Others that may be included are cream, ice cream, eggs, whole milk, and cheese made from whole milk or mixtures of milk and cream. The dairy products demonstrate once more their great value in the satisfactory nutrition of man. Meats are usually not good sources of vitamin A, although fats contain the vitamin. Liver is a good source of vitamin A, but its concentration varies considerably. The green and yellow vegetables like yellow corn, sweet potatoes, carrots, spinach, lettuce, Brussels sprouts, cabbage, squash, pumpkin, string beans, and peas are also good sources of vitamin A. Among the fruits, tomatoes, cherries, canteloupes, alligator pears, watermelon, apples, grapes, and pineapples may be mentioned. Most nuts and cereals are not good sources of vitamin A and among the vegetable oils, the amount present varies inversely with the extent of refining and hydrogenation. Fresh olive oil and corn oil contain appreciable amounts of vitamin A.

Vitamin B or B_1. — This vitamin is known as the anti-beriberi or the anti-neuritic vitamin. It is water soluble, and its presence in food will either prevent or cure the disease beriberi. This disease. which has been prevalent in the Orient for centuries,

where polished rice has often been the sole source of food among the poor, attacks the nerves of both feet, gradually extending up the legs, and if not checked results in paralysis and death. The work of Eijkman and other investigators on the etiology and cure of beriberi has already been described. More recent work has shown that the anti-neuritic vitamin is essential not only for the prevention of polyneuritis or beriberi, but likewise for the support of growth and the maintenance of appetite.

Much of the work done in the past on vitamin B is confusing because no effort was made to distinguish its effects from those due to its associated vitamin, B_2 or G. The demonstration of this complex was made possible by showing that the anti-neuritic principle was more readily destroyed by heat, *i.e.*, more heat-labile. Vitamin B (B_1) is destroyed at a temperature of 115° to 120° C. in from one to two hours, but deterioration at lower temperatures also occurs even though the rate is much slower. It is comforting however to know that the temperature and time ordinarily employed in cooking produces only an insignificant destruction of this vitamin. However, the resistance of the vitamin to heat is influenced to a remarkable degree by the presence of acid or alkali. Increasing alkalinity brings about a rapid destruction of this vitamin at high temperatures, 100° C. or higher, whereas high acidity protects the vitamin against material destruction even at the same temperatures. For this reason canned tomatoes show no appreciable reduction in vitamin B over that contained by the fresh fruit. At low temperatures, however, the vitamin is not affected materially by the reaction. The vitamin is not materially affected by oxidation, nor is it greatly influenced by ultraviolet irradiation if the treatment is not prolonged. In dry form, as in lentils and seeds, it has been stored for 38 years without any appreciable reduction.

Vitamin B is widely distributed in foods. It is found in oats, corn, wheat, wheat embryo, the outer layers of rice, rice polishings, red kidney beans, milk, liver, kidney, eggs, yeast, and the fruits and vegetables.

Vitamin B_2 or G. — Since 1919 when it was shown that the anti-beriberi element in vitamin B could be destroyed by autoclaving at certain temperatures for a given period of time without destroying the growth-promoting element found in the same vitamin. considerable doubt has existed concerning the unity of

the water-soluble B vitamin responsible for the prevention of beriberi. In other words vitamin B was shown to be a complex, consisting in part of a thermo-labile anti-neuritic element and in part of a thermo-stable growth-promoting element. Whether or not there are still other fractions in the vitamin B complex is an open question which only future research will disclose.

The dual nature of vitamin B was definitely established in 1926 as a result of the researches of Goldberger, Wheeler, Lillie, and Rogers on the etiology of pellagra. After destroying the anti-neuritic vitamin in yeast by autoclaving, these workers demonstrated that the yeast was still effective in the prevention and cure of human pellagra as well as the pellagra-like disease in dogs, called black tongue. This thermo-stable substance was first called the P-P element, or the pellagra-preventive element, and has subsequently become known as vitamin B_2 or G. While it is now accepted that the same food may contain both vitamins B_1 and B_2, it is not yet universally agreed that the lack of vitamin B_2 or G is responsible for the development of all cases of human pellagra, even though it may give rise to pellagra-like symptoms in smaller animals. The relationship of vitamin B_2 to growth and to satisfactory nutrition at all ages is however generally accepted. Vitamin B_2 like B_1, is also injuriously affected when heated at high temperatures — 100° C. — if the reaction of the medium is alkaline. In an acid medium, *i.e.*, at pH 5.0, it can be heated at this temperature for at least two hours without showing any diminution in potency.

Vitamin B_2 is found in a large variety of foods. It is found in the muscles and body tissues of animals, the concentration varying with the amount contained in the food. In the animal body the liver appears to be the storehouse for this vitamin, the quantity found being dependent once more on the amount present in the food. Milk is probably the most important source of vitamin B_2 in the American dietary, and contains more of this element than it does of vitamin B_1. Other sources of vitamin B_2 are cream and ice cream, yeast (fresh, dry, or autoclaved), kidney, liver, egg yolk, eggs, spinach, carrots, lean beef, heart, bacon, cauliflower, oranges, watercress, turnips, lettuce, beets, beet-tops, cabbage, pears, and bananas. Cereal grains and seeds generally also contain vitamin B_2, but they are poorer in this vitamin than in vitamin B_1.

Vitamin C. — This vitamin is also water-soluble and is often referred to as the anti-scorbutic vitamin. It is a specific preventive and cure for scurvy, a disease which afflicted man for centuries and which invariably appeared among sailors, explorers, and others engaged on long voyages or travels and compelled to subsist on diets devoid of fresh foods. With the advent of refrigeration, canning, and dehydration in the preservation of foods, scurvy disappeared rapidly. Its former prevalence in the British Navy was combated successfully by the addition of lime juice to the daily dietary of the men. Although serious cases of scurvy do not occur with great frequency in civilized communities today, latent scurvy or the early symptoms of scurvy apparently occur quite extensively. The human body is unable to store up the anti-scorbutic substance to any marked degree, and is therefore dependent on a constant supply of this element in the daily dietary.

Some of the acute symptoms of scurvy are hemorrhages, fragility of the bones, and loose teeth. Latent scurvy however seems to pave the way for the development of bacterial infections by lowering the resistance of the animal body; it is responsible for more or less retarded growth; it interferes with the normal growth and calcification of the teeth and has been associated with the development of dental caries and the poor healing of experimental bone wounds; similarly, it was associated with the slow healing of wounds during the war; it is also supposedly responsible in many cases for a sallow muddy complexion, for loss of energy, and for fleeting, rheumatic pains in the joints and limbs.

In 1907 Holst was invited to study the feeding of Norwegian soldiers and as a result of his work experimental evidence was presented in 1912 to the effect that scurvy was a deficiency disease and that it could be prevented by the addition of anti-scorbutic foods such as green vegetables and fruits to the diet. Since then the subject has been studied extensively, and the relationship of the water soluble C vitamin to scurvy has been definitely established. In 1932, Rygh of Upsala University claimed to have established the synthesis and chemical identity of this vitamin, but this was proved to be an error. In 1933, however, the chemical nature of vitamin C was determined. It was found to be one of the hexuronic acids and is now designated as ascorbic acid. Harris and Ray of the Nutrition Laboratory in

Cambridge, England, reported in 1933, that 2 mgms. of ascorbic acid are equivalent in anti-scorbutic potency to 3 cc. of orange juice. The minimum daily requirement of orange or lemon juice is estimated to be 30 cc. (1 oz.) or about 20 mgms. of ascorbic acid.

Scientists have been much concerned over the extent to which vitamin C in milk, tomatoes, and other foods is destroyed by pasteurization, canning, and other processing. The evidence now seems clear that milk is not ordinarily a rich source of vitamin C, the amount present in raw milk depending entirely on the vitamin C content of the cattle food. Pastured cows yield milk richer in vitamin C than stall fed animals unless the ration of the latter includes ensilage of good quality and high vitamin C content. It is true however that vitamin C is more or less readily destroyed if heated in contact with air or oxygen, particularly if the medium in alkaline in reaction. If the reaction of the medium is acid and the heating is accomplished rapidly, especially in the absence of oxygen, the vitamin does not suffer any serious deterioration. The commercial pasteurization of milk in the United States results in a diminution of the vitamin C content varying from 25 to 33 per cent. Evaporated milk, which is sterilized by heat, shows very little if any vitamin C. On the other hand, condensed milk which is preserved in part by a high sugar concentration, shows only a small reduction in the vitamin C content of the original milk. Powdered milk also retains most of the vitamin C found in the original milk, and in the dry form the vitamin retains its potency for a long time.

Recent investigations indicate that in cold storage and in canning the rate of reduction in vitamin C varies greatly with different foods. This is true both for fruits and vegetables. However, grapefruit and tomatoes do not show any diminution in vitamin C content during canning and subsequent storage, and citrus fruit juices can be preserved by desiccation without serious deterioration of vitamin C if suitable precautions are taken. Strawberries preserved by the quick-freezing process also do not show any serious diminution in vitamin C.

Among the richest sources of vitamin C are the fruits and vegetables. Included in this group are oranges, lemons, grapefruit, tomatoes, apples, bananas, strawberries, raw cabbage, carrots, potatoes, string beans, fresh corn, parsley, peas, peppers, and

spinach. Paprika is also an excellent source of vitamin C. The introduction of potatoes in Europe helped materially in combating scurvy, for although the concentration of vitamin C in the potato is not high, the amount consumed is normally large. Sprouted seeds are also rich in vitamin C, while resting seeds are deficient.

Vitamin D. — This vitamin is fat-soluble and is known also as the anti-rachitic vitamin. The solution of the rickets problem is an achievement of the twentieth century. At one time rickets was widespread. Its prevalence in England was so great that the Germans identified rickets as the "English disease." The disease was especially prevalent in the temperate regions of the world, and particularly in the large, industrial cities. It is more prevalent in winter than in summer and among colored children in the north than among white children. For a long time it was associated with poverty, poor housing, and general unhygienic conditions. In its acute form rickets is characterized by enlarged joints, bow-legs, knock-knees, deformities of the spinal column and pelvis, enlarged head, and severe deformity of the chest. It is also associated with a prominent abdomen, flabby muscles, sweating of the head and delayed teething. While rickets is rarely fatal it often leads to complications and other diseases which are more serious.

The first definite evidence that rickets is a dietary deficiency disease was presented by Mellanby of England in 1919, who produced experimental rickets in puppies with a diet deficient in calcium and vitamin D. He also showed that the addition of a few cubic centimeters of cod liver oil to the diet prevented the development of rickets, and cured it when present. He assumed erroneously that the lack of fat soluble A was responsible for the development of rickets. At that time there was no distinction between vitamins A and D, and vitamin A was supposed to contain the anti-rachitic factor. In 1922, however, McCollum and his co-workers at Johns Hopkins University proved that there were at least two fat-soluble vitamins, one of which, vitamin A, could be destroyed by oxidation at 100° C. for 12 to 14 hours, and another, vitamin D, which was not affected, proved to be the specific anti-rachitic factor.

However, rickets is not due to a deficiency in vitamin D alone. Rickets develops when an insufficient amount of calcium or phosphorus or both elements is deposited in the bones for the development of bone tissue. If the diet is seriously deficient in one or both

of these elements, rickets may occur in spite of the presence of vitamin D. But in order for calcium and phosphorus to be utilized promptly and effectively for the development of bone tissue, vitamin D must be present. The presence of the vitamin paves the way for and facilitates the normal metabolism and absorption of the calcium and phosphorus in the diet.

In 1890 Palm observed that sunlight was effective in the prevention and cure of rickets, but it was not until 1919 that the mechanism involved was elucidated. In that year, Huldschinsky, a German physician working in Berlin, reported that he had been able to cure rickets in children successfully by exposing one or both affected limbs to the radiations from the mercury vapor quartz lamp. He reported further that when these rays — the ultraviolet rays of the spectrum — were removed by glass filters, no healing effects were observed. It was evident therefore that exposure to ultraviolet light or the taking of cod liver oil by mouth produced the same anti-rachitic effects. In 1924 Hess of New York and Steenbock of Wisconsin demonstrated independently that anti-rachitic potency could be established in many foods by irradiation with ultraviolet light. It was only necessary for ergosterol to be present, and this substance in the presence of ultraviolet light developed vitamin D or anti-rachitic properties. Since ergosterol is present in the skin, direct irradiation with ultraviolet light produces the same effect as the taking of cod liver oil by mouth. Ergosterol is widely distributed in plant and animal tissues, although its concentration is usually less than one per cent. The two chief sources of supply for commercial purposes are ergot and yeast. Viosterol which is used extensively as a preventive against rickets in infants and children is irradiated ergosterol. The ultraviolet light which has potent anti-rachitic properties has a wave length between 302 and 280 millimicrons or between 3,020 and 2,800 Ångstrom units. Rays of shorter wave length are not very effective in endowing ergosterol with anti-rachitic properties and rays having a wave length in excess of 313 millimicrons cease to have anti-rachitic properties. Over-irradiation of vitamin D with ultraviolet light finally destroys it, but the vitamin is relatively stable to oxidation.

The value of vitamin D is probably not limited to its anti-rachitic effects. It is supposed to exert a wholesome effect on the general well-being of the individual and to fortify the organism

against respiratory diseases. It is also of great value to the expectant and lactating mother since the embryo is dependent on its mother for the entire food supply, and the anti-rachitic potency of mother's milk is dependent on the vitamin D intake. Vitamin D taken into the body is not given up immediately, but may be stored to a remarkable degree. The vitamin is not materially affected by temperatures used in cooking, and prolonged storage at low temperatures, 4° to 5° C., does not diminish its potency.

The best sources of vitamin D in foods are cod liver oil, haliver oil, and numerous fish oils such as salmon oil, tuna fish oil, sardine oil, and herring oil. It is also found in shrimps and oysters. Egg yolk is normally also a rich source of vitamin D, but its potency varies with the degree of irradiation to which the hens have been exposed and with the vitamin D content of their diet. Butterfat and other dairy products including whole milk contain relatively little of the anti-rachitic factor unless special precautions have been taken to build up the vitamin D potency of milk. This can be done in a variety of ways — described in the chapter on milk supplies — and recently vitamin D milk has been made available by a number of producers. Summer milk contains more vitamin D than winter milk. Vegetable foods, even the green leafy vegetables, are ordinarily lacking in vitamin D. Similarly the vegetable fats are also deficient. The vegetable margarines are devoid of vitamin D, but the oleomargarines made of animal fats, such as beef oleo oil, contain appreciable amounts of vitamin D. The cereals are also devoid of this important element.

A great deal of successful work has been done during the past ten years in endowing various foods with anti-rachitic properties by irradiation. Numerous oils and fats, such as olive oil, cottonseed oil, linseed oil, corn oil, cocoanut oil, lard, oleomargarine, and butter have been activated in this way. Cereal products, including refined wheat flour, whole wheat flour, shredded wheat, cream of wheat, and cornstarch have also been successfully activated. Likewise meat, whole milk, powdered milk, chocolate, ice cream, orange juice, yeast, and various vegetables. The vitamin D potency of egg yolk and butter has been increased ten- to twentyfold by irradiation. In fact, sugar seems to be the only natural food that has not been irradiated successfully for vitamin D potency.

Vitamin E. — This vitamin is also fat-soluble, is different from vitamins A and D, and is known as the anti-sterility vitamin. It

was discovered in 1922 by Evans and Bishop of the University of California and the work described by them has been substantiated by other American and British investigators. The lack of this vitamin in the diet of experimental animals resulted in the death and absorption of the fetus. It is unfortunate that the vitamin has been linked so prominently with reproduction, since vitamin A is at least equally important for successful reproduction, and the lack of vitamin E has never been associated with dietary deficiencies in man.

Vitamin E is widely distributed among animal and plant foods and is found in meat, milk, butter, the cereals and grains, and in vegetables. Vegetable oils, and particularly wheat germ oil, are rich in vitamin E. It is relatively stable to heat. The fact that it is present so frequently in human foods makes it unnecessary to lay special emphasis on this element in formulating the human dietary.

The vitamin content of foods. — The following table showing the vitamin content of foods was prepared from data presented in the *Monograph on the Vitamins* by Ethel Browning, M.D., of the Pickett–Thomson Research Laboratory in London, which was published in 1931.

TABLE 33

THE VITAMIN CONTENT OF FOODS

Key to symbols

+++ very rich + fairly rich − absent
++ rich ± some present D doubtful

Class of Foods	Individual Food	Vitamin A	Vitamin B1	Vitamin B2	Vitamin C	Vitamin D	Vitamin E
Animal foods and tissues	Bacon	− to +	+				
	Beef muscle	±	±	+	− to +		+
	Buttermilk	+			− to +		
	Casein	+	+	+	−		
	Cheese	++					
	Eggs (hens')	++	++		−		
	Egg yolk	++	+	++	−	++	++
	Egg white	−	−		− to +	−	
	Fish: cod, haddock, salmon	+	− to +	+		+	
	Salmon (canned)	+		++			

TABLE 33—*Continued*

THE VITAMIN CONTENT OF FOODS

CLASS OF FOODS	INDIVIDUAL FOOD	VITAMIN A	VITAMIN B₁	VITAMIN B₂	VITAMIN C	VITAMIN D	VITAMIN E
Animal foods and tissues	Oysters	+	++		+	++	
	Ham	− to +	++				
	Heart	++	++		+		
	Kidneys	+	++		+		+
	Lamb or mutton	− to +	+				
	Liver	++	+	+	+		+
	Beef	++	+	++			++
	Chicken		+		+		
	Cows' milk, raw	+++	+	++	− to +	− to +	− to +
	(Condensed)	++	− to +		+		
	(Powdered)	++	++		− to +	+	+
	(Evaporated)	++	+	++	− to +		
	Pancreas (sweetbreads)	+	+				
	Pork	− to +	++	++	+		
	Veal	− to +	+				
Animal oils and fats	Beef fat	++	−			± to +	+
	Butter	+++	−		−	± to +	± to +
	Cream	++	+		− to +	±	
	Cod liver oil	+++	−		−	+++	
	Fish body oil	++				++	
	Lard	− to +	−	±	−	−	−
	Oleomargarine	+	−		−		
Vegetable oils and fats	Almond oil	−					
	Peanut oil	±	−		−		− to +
	Cocoanut oil	−	−		−	±	low
	Corn oil	±	−		−	− to +	low
	Cottonseed oil	− to +	−		−	±	± to +
	Linseed oil	±					low
	Maize oil	+	−		−	+	low
	Olive oil	− to +	−		−	±	− to +
	Soy bean oil	− to +					− to +
	Wheat germ oil	±					+++
Cereals and cereal products	Barley						
	(unhusked)	+	+		−		
	(husked)		±				
	(sprouted)	+	++		++	+	probable
	Bread						
	(white)	−	− to +		−		
	(wholemeal)	+	++		−		
	Corn (Maize)						
	(yellow)	+	+	±	−	low	
	(white)	−					

TABLE 33—*Continued*

THE VITAMIN CONTENT OF FOODS

Class of Foods	Individual Food	Vitamin A	Vitamin B₁	Vitamin B₂	Vitamin C	Vitamin D	Vitamin E
Cereals and cereal products	Flour (white)	almost −	−	almost −			
	(irradiated)					+	
	(wholemeal)	±	±	±	−		
	Oats	− to +	+		−		
	Oatmeal	− to +	+		−		
	Rice (whole)	+	+		−	almost −	
	(polished)	−	−		−		
	Rye (whole)	+	+		−		
	Wheat (whole)	+	++	±	−		+
Seeds and nuts	Almonds	++	+				
	Brazil nuts	very low	++		probably absent		
	Butternuts	very low	++				
	Chestnuts		+				
	Cottonseed	+	+				
	Filberts		++				
	Hazel nuts		+				
	Hickory nuts		++				
	Linseed	++	++				
	Peanuts	low	++				+
	Pecans	+	++				
	Walnuts (English)	low	++				
Vegetables and vegetable products	Alfalfa	++	+			almost nil	+
	Artichokes	+	+				
	Asparagus	++	++				
	Beans (red kidney)		+	+			
	(navy)		+				
	(soy)	low	++				
	(string)	+	++		+		
	Beets	±					
	Beet leaves and stems	++	++				
	Cabbage (green leaves)	++	++	+	+++	+	+
	(white leaves)	− to +			+++		
	Carrots, young, (raw)	+++	++	+	++	±	

TABLE 33—*Continued*

THE VITAMIN CONTENT OF FOODS

Class of Foods	Individual Food	Vitamin A	Vitamin B1	Vitamin B2	Vitamin C	Vitamin D	Vitamin E
Vegetable and vegetable products	Cauliflower, (raw)	+	+		+		
	Celery	+	++				
	Chard	++	++				
	Clover	++	+			+	
	Cucumber	− to +	+		++		
	Dandelion greens	++	+		+		
	Egg plant	+	+		+		
	Endive	+			+		
	Escarole	+++					
	Kale	++					
	Lentils (dried)	+	++		low		
	Lettuce	++	+	+	++	−	+++
	Mushrooms	low	++		−	−	
	Okra		+++				
	Onions (raw)	−	+		++		
	Parsley		++				
	Parsnips	− to +	++				
	Peas (green)	++	++		+++		
	Peas (canned)	++	+		++		
	Peppers (green)	++	++		+++		
	Potatoes	±	+		++		
	Pumpkin	++	+		+		
	Radishes	−	+		++		
	Rhubarb				+		
	Spinach (raw)	+++	++	++	++	− to +	
	(canned)	++	+		++		
	Squash (Hubbard)	++					
	Sweet potato	++	+		++		
	Tomatoes (raw)	++	++		+++		
	(canned)	++		±	++		
	Turnips	− to +	+	− to +	+		
	Watercress	+++			+++		
Fruits	Apples (raw)	+	+		++		
	Apricots (dried)	+					
	Alligator pear	++	++		− to +		
	Banana	++	+	++	+++	− to ±	+
	Canteloupe	++	++		++		
	Cherries (canned)	++	++				
	Grapefruit	+	+		+++		

TABLE 33—*Continued*

THE VITAMIN CONTENT OF FOODS

CLASS OF FOODS	INDIVIDUAL FOOD	VITAMIN					
		A	B_1	B_2	C	D	E
Fruits	Lemons	±	++		+++		
	Limes	+	+		++		
	Orange	+	+		+++		
	Peaches	+	+		+		
	Pears (raw)		+		++		
	Pineapple						
	(raw)	++	++		++		
	(canned)	++	++		++		
	Raspberries				+		
	Strawberries						
	(raw)	±	+		+++		
Miscellaneous	Beer		0 to +				
	Honey	−	−		−		
	Yeast						
	(moist)	− to +	+++	++	−	−	
	(dried)	−	++	+	−		
	(irradiated)					++	

CHAPTER XXV

PUBLIC HEALTH ASPECTS OF TUBERCULOSIS

One of the remarkable achievements of sanitary and medical science during the past fifty years has been the progress in the conquest of tuberculosis. This disease was, until 1908, the most important single cause of death. As an agent of destruction, especially during the prime of life, and wrecker of the unity of families, tuberculosis has left immeasurable ruin and misery in its wake for centuries. Few families have escaped the incursions of this insidious, devastating plague, spreading slowly from one individual to another, until all were infected and many had succumbed. It is little wonder that it has been called "The Captain of the Men of Death."

Tuberculosis is perhaps still the most widely distributed of all the communicable diseases that affect man. It is found in all parts of the world wherever human beings have congregated in social groups, and is one of the accompaniments of civilization. Dr. Osler used to advise physicians to eliminate all doubt of tuberculosis and syphilis in making a diagnosis before concluding that any other disease was at fault.

The tuberculosis toll. — It is impossible to estimate accurately the toll in human life, economic disaster, and misery for which tuberculosis has been responsible. Dr. F. L. Hoffman, consulting statistician for the Prudential Life Insurance Company, in an article entitled "A Century's Holocaust of the Tubercle Bacillus," estimated that from 1812 to 1924, there were 665,803 deaths from pulmonary tuberculosis alone in New York, Philadelphia, and Boston. During the period from 1812 to 1828, the death rate from pulmonary tuberculosis in the large eastern cities of the United States was approximately 400 per 100,000. From 1839 to 1852 the death rate apparently receded to about 350 per 100,000 population, mounting again in the period 1852–1882 to approximately 400 per 100,000 population. These data are doubtless indicative of the conditions that prevailed in the country as a whole, and in fact, throughout the civilized world during that era.

On March 24, 1882, Robert Koch made the announcement before the Physiologische Gesellschaft in Berlin of the discovery that a microbe, the tubercle bacillus, was the cause of tuberculosis. Prior to that time all sorts of fallacious theories were extant concerning the origin and cause of this universal affliction. The announcement of this fundamental discovery was revolutionary. Despair was changed to hope. With definite knowledge of causation assured, constructive progress in its study and control was possible. No more might tuberculosis be considered a visitation of the wrath of God; or even regarded as a house or "block" disease; or associated with the breathing of night air and other vagaries. From the time of Koch's pronouncement it began to be recognized as a germ disease transmitted primarily from one individual to another. With the development of this knowledge came new methods of attack upon the disease, so that, since 1882, the mortality from tuberculosis has been diminishing almost without interruption. Today thoughtful students of the subject are beginning to vision the day when tuberculosis may take its place with the other "conquered" diseases such as typhoid fever, diphtheria, and smallpox.

No accurate estimate of the early toll of tuberculosis is obtainable because of the absence of reliable statistical information, but with the organization of the U.S. Death Registration Area in 1900, such information became available from then on. An examination of some of these data will therefore be of value in tracing the progress made against this disease in modern times.

TABLE 31

DEATH RATE FROM TUBERCULOSIS, ALL FORMS, ORIGINAL REGISTRATION AREA, 1900–1932

YEAR	DEATH RATE PER 100,000 POPULATION	PER CENT REDUCTION SINCE 1900
1900	195.2	
1910	164.7	15.6
1920	112.0	42.6
1925	82.9	57.5
1930	71.5 [1]	63.3

[1] U.S. Registration Area.

In Massachusetts the death rate from pulmonary or respiratory tuberculosis fell from 181.3 per 100,000 population in 1900 to 57.0 per 100,000 in 1930, a reduction of 68.6 per cent. In 1932 the rate dropped to 47.5, a reduction of 73.8 per cent from 1900. The death

rate from all forms of tuberculosis in Massachusetts during the ten-year period from 1923 to 1932 fell from 90.4 per 100,000 population to 53.5, a reduction of 40.8 per cent. In the city of Boston the death rate from tuberculosis, all forms, diminished from 289.8 per 100,000 population in 1900 to 66.1 per 100,000 population in 1932, a reduction of 77.1 per cent. This improvement was not local but country wide. For example, in Detroit the death rate from tuberculosis, all forms, diminished from 95.5 per 100,000 population in 1923 to 70.3 in 1932. In New York, the great, congested metropolis of the United States, the death rate from pulmonary tuberculosis alone between 1920 and 1931, fell from 108.47 per 100,000 population to 61.64, a reduction of 43.1 per cent.

TABLE 35

DEATH RATES FROM PULMONARY TUBERCULOSIS PER 100,000 POPULATION IN 1930 FOR 26 LARGE CITIES IN VARIOUS PARTS OF THE WORLD

City	Death Rate from Pulmonary Tuberculosis
Chicago	56.8
New York	64.0
Detroit	68.2
Philadelphia	71.3
Los Angeles [1]	103.9
Amsterdam	52.5
Rotterdam	55.3
Hamburg	65.6
Berlin	83.7
Greater London	78.8
Glasgow	79.5
Birmingham	90.0
Manchester	116.7
Liverpool	119.3
Milan	78.4
Turin	95.2
Rome	110.9
Naples	111.7
Prague	133.3
Vienna	135.5
Warsaw	171.9
Bombay	111.6
Tokyo	133.5
Hong Kong	174.4
Osaka	187.6
Calcutta	240.5

[1] The high death rate in Los Angeles is due to the large number of non-residents who seek treatment there.

In view of the interest which comparative mortality statistics hold, the preceding table, taken from the *Weekly Bulletin* of the New York City Health Department for November 5, 1932,* showing the death rate from pulmonary tuberculosis in 1930 in the five largest cities of the United States and 21 large cities in other parts of the world, is presented. The data for Tokyo and Osaka are for 1929.

The data presented in the preceding table indicate that the death rates from pulmonary tuberculosis in the large cities of the United States compare favorably with the rates prevailing in other large centers of population throughout the world. In some of these centers progress against the ravages of the Great White Plague has as yet been slow. Improvement will doubtless come in time through the development of suitable public health and anti-tuberculosis programs and the elevation in the standard of living.

What is the outlook for tuberculosis in the United States? According to the *Statistical Bulletin* of the Metropolitan Life Insurance Company for December, 1932, the death rate from all forms of tuberculosis for the original U.S. Registration Area should be less than 40 per 100,000 population by 1940. In 1931 there were 29 cities with a population of 100,000 or more in which the death rates from pulmonary tuberculosis were below 50 per 100,000. Of these, Rochester, N.Y., had reached the remarkably low rate of 23.2 per 100,000 population; Syracuse, N.Y., 24.8; and Utica, N.Y., 30.2. This is in striking contrast to the estimates of the prevalent mortality of earlier times Rollo H. Britten,† Senior Statistician of the U.S. Public Health Service, has shown that the estimated phthisis (consumption or pulmonary tuberculosis) mortality in England and Wales during the last quarter of the eighteenth century was approximately 650 per 100,000 population.

The present significance of tuberculosis. — The outstanding progress which has been made against tuberculosis should not lead one to the conclusion that tuberculosis is no longer a serious disease. It is true that numerically tuberculosis has receded from first to seventh place as a cause of death in the United States, but it is still the predominant cause of death in the early and middle adult age groups, which are the most productive and important periods from the standpoint of family life and national or community usefulness. Until this significant relationship of tuber-

* Compiled by Dr. Frederick Hoffman.

† *U.S. Public Health Reports*, January 13, 1933.

culosis to the years under forty-five is eliminated, tuberculosis must always be considered of major public health importance. Until then the campaign against the disease must not be relaxed.

As recently as 1927 tuberculosis was the most important cause of death in Illinois in the age groups 15 to 19, 20 to 24, 24 to 29, and 30 to 34, and a close second to organic heart diseases as a cause of death in the age group 35 to 44. Tuberculosis was not included among the first ten causes of death in infancy, but in the age group 1 and 2 it was fifth in importance; in age group 3 and 4 it ranked fourth; in age group 5 to 9 it ranked fifth; and in the age group 10 to 14 it ranked third. In the late adult groups it lost some of its significance. In the age group 45 to 54 it ranked fifth as a cause of death; but in the age group 55 to 64 it had receded to seventh place; in the age group 65 to 74 it occupied ninth place; and after 75 it was no longer listed among the first ten causes of death. It is obvious, therefore, from this further analysis, that tuberculosis must still be regarded as of major importance, even more important than those degenerative diseases which afflict man in the late years of life particularly, and which may show a higher mortality rate. Since the absolute span of life has not and perhaps cannot be lengthened, it is wiser to seek to protect and to insure the activity of those of greatest virility, responsibility, and achievement.

Tuberculosis and nativity. — Since a proper evaluation of the significance of any cause of death can be obtained only by studying it in all of its statistical relations, a thorough analysis of the composition and socio-economic aspects of the population must be made as well as the statistical analysis of disease and mortality. In some cities, *e.g.*, New York, Boston, and Cleveland, arrangements have been made in recent years to analyze the population and vital statistics by "census tracts," *i.e.*, small areas, permanent in their boundaries, and chosen for study because of definite sociological reasons and without regard to political significance. In this way information of great value in the conduct of the public health campaign is made available.

Such an analysis is particularly significant in the case of tuberculosis. A high or low death rate from tuberculosis may be explainable, in part at least, by knowledge of the racial composition and age distribution of the population. It has been known for years that certain racial groups suffer more extensively from tuberculosis than do others. The American Indian and negro suffer enormously

in comparison to the white race. The Mongolians, including the Chinese and Japanese, also show high death rates from tuberculosis. But even among the white race the rates vary greatly, the death rates among Russians, Poles, Irish, Scandinavians, Puerto Ricans, and others being high, while comparable rates for the Jews and Italians are exceedingly low. The reason for this interesting biological phenomenon is not clear. It may be that the susceptibles in these two latter named groups have been largely weeded out in the march of time and only those who are resistant to tuberculosis have survived. Numerous other factors may be involved, however, such as greater adaptability to urban conditions of life, freedom from alcoholic excesses, or variations in occupation. But marked variations in the death rates from tuberculosis exist among the Jews and Italians themselves, depending in part on their economic status, occupations, and hygienic practices, but in general, the death rates from tuberculosis among these two groups are lower than in the rest of the population. In New York, for example, Bolduan and Weiner have shown in 1932, that not only is the death rate from tuberculosis among Jews much lower than among non-Jews, but that between the ages of 30 and 50, the proportion of tuberculosis deaths among Jewish males was approximately one-third the number found among non-Jewish white males.

With the passage of time and the gradual assimilation of the foreign-born population in the United States, the marked discrepancies existing in the tuberculosis mortality among different national groups tend to disappear. This fact is supported by evidence presented in *U.S. Mortality Report for 1921*. The data, given below, refer to the variations in the death rates among Irish of foreign-born and native-born mothers.

TABLE 36

Death Rate from Pulmonary Tuberculosis per 100,000 White Population in Boston for Males and Females, for Those of Irish Origin Whose Mothers Were Born in the United States or Ireland, for 1900, 1910, and 1920

Year	Males		Females	
	Mothers Born in the U S	Mothers Born in Ireland	Mothers Born in the U.S	Mothers Born in Ireland
1900	130	430	100	330
1910	90	360	80	210
1920	60	180	60	160

Data on foreign-born groups in New York City, but without regard to sex, were published in the *Weekly Bulletin* of the New York City Health Department for October 29, 1932, and are recorded in the following table. The low death rates for Russia, Poland, and Austria-Hungary are probably due to the fact that the foreign born of these countries are largely of Jewish origin. On the other hand, the high death rate found among Puerto Ricans, of which there has been a marked influx into New York within recent years, indicates at least one of the serious public health problems which this biological phenomenon has created. The table also illustrates the variations in tuberculosis mortality for people of different national origins. The fact that the death rate has diminished so rapidly in some instances is explained by the restriction of immigration and the gradual elimination of the foreign born from those age groups in which tuberculosis mortality is very high.

TABLE 37

Death Rates from Pulmonary Tuberculosis per 100,000 Population in Each Group among Foreign Born in New York City for 1920 and 1921, and 1930 and 1931

Country of Birth	1920 1921	1930 1931
China	930	580
Puerto Rico	—	461
Ireland	229	127
Scandinavia	150	24
Austria-Hungary	133	78
Italy	107	53
Germany	105	45
England	100	60
Russia	70	50
Poland	—	42

Tuberculosis in relation to age and sex. — The significance of tuberculosis for different age groups has been previously mentioned, but a more intimate picture of the situation can be obtained by viewing specific data on the subject. Such information is available by age groups alone and for age and sex combined. The latter is especially valuable in helping the student to observe some of the significant variations in tuberculosis mortality.

TABLE 38

DEATH RATES FROM TUBERCULOSIS, ALL FORMS, PER 100,000 POPULATION IN CERTAIN MASSACHUSETTS CITIES, DISTRIBUTED ACCORDING TO AGE *

AGE GROUP	BOSTON 1924	CAMBRIDGE 1922–1926	HOLYOKE 1924-1928
Under 1	193.6	40.1	113.3
Under 5	120.0	43.3	64.2 [1]
5– 9	25.8	5.7	24.1
10–14	26.4	31.9	14.6
15–19	72.7	105.1	90.0
20–24	120 4 (20–29)	118.5	109.9
25–34	105.0 (30–39)	113.8	113.7
35–44	104 6 (40-49)	118.8	144.3
45–54	138 9 (50–59)	108.8	140.2
55–64	168.3 (60–69)	102.4	150.3
65 and over	116.4 (70 and over)	68.6	112.0
All ages	100 8	87.3	98.5

[1] For age group 1–4.

The data presented in the preceding table indicate that there is a high death rate from tuberculosis in infancy and during the pre-school period, and that the mortality subsides during the grade school period. Beginning approximately with the high school period, the mortality from tuberculosis increases and remains high during the active, adult period of life. Toward the end of life, when tuberculosis has already taken its toll, and when the degenerative diseases begin to show evidence of their insidious progress, the mortality from tuberculosis tends to diminish.

Of greater significance, however, is the variation in tuberculosis mortality by age and sex. The death rate from tuberculosis among males for all age groups, is materially higher than the rate for females. In this respect, the female shows possibly the advantage of the greater protection and freedom from health hazards and devitalizing influences which her more sheltered domestic existence affords. But the advantage is not with the female in every age group. At certain ages, she shows a higher death rate from tuberculosis than is found among males, and it is particularly disconcerting that in these age groups, the death rate from tuberculosis is declining much more slowly than among males. This situation is true throughout the United States, and the evidence presented here is typical of the general condition.

* From data presented by M. P. Horwood in *Tuberculosis Survey Reports of Boston, Cambridge, and Holyoke, Mass.*

TABLE 39

DEATH RATES FROM TUBERCULOSIS, ALL FORMS, PER 100,000 POPULATION FOR CERTAIN MASSACHUSETTS CITIES, DISTRIBUTED ACCORDING TO AGE AND SEX *

Age Group	Boston 1920–1924		Cambridge 1922–1926		Holyoke 1924–1928	
	Male	Female	Male	Female	Male	Female
Under 1	145.3	113.7	65.0	16.3	163.4	64.3
Under 5	71.4	58.1	41.1	45.4	54.8[1]	71.0[1]
5– 9	10.5	16.3	3.8	7.8	34.3	13.9
10–14	10.7	14.9	8.0	55.6	7.3	21.7
15–19	31.0	48.7	90.8	118.7	40.2	134.6
20–24	58.1	79.8	94.1	139.3	52.8	157.5
25–34	67.9	59.2	122.8	105.7	118.0	109.5
35–44	87.7	46.5	142.6	95.6	180.3	110.9
45–54	101.9	37.7	162.9	59.8	183.0	99.0
55–64	97.9	48.2	136.0	74.2	216.2	87.4
65 and over	55.7	52.1	138.0	22.8	136.5	92.3
All ages	124.2	98.9	97.0	78.5	103.0	93.2

Beginning with age 20, the data for Boston are presented in 10 year groups, *i.e.*, 20–29, 30–39, etc.

[1] For age group 1–4.

The higher death rate among females during puberty, adolescence, and early motherhood is difficult to explain. Doubtless the revolutionary biological changes that take place in the female organism during this period of her existence, coupled with excesses of nervous and emotional strain and fatigue, and accompanied by improper hygienic practices, result in the present condition. It has long been known that even incipient tuberculosis is complicated by pregnancy, and that the combination is often fatal. Once the female organism has become adjusted to the reproductive function, she shows the benefits of her more sheltered life. It is evident that the prevention of this seemingly unnecessary tuberculosis mortality among young women represents a serious sociological problem and a public health challenge.

On the other hand, the male past the age of 25 shows the ill effects of the wear and tear which his more strenuous physical life entails. Industry with its long hours of confining work, with dusts that are not removed, with inadequate ventilating systems, with excess heat and humidity in the atmosphere, with excess fatigue, perhaps also with inadequate or unsatisfactory nutrition, takes its

* From data presented by M. P. Horwood in the *Tuberculosis Survey Reports of Boston, Cambridge, and Holyoke, Mass.*

toll in human life eventually, and tuberculosis is one of its great allies. The death rate from tuberculosis among white males becomes larger than the death rate among white females beginning with ages 25 to 34. The discrepancy grows greater until age 55, after which the differences tend to become smaller, although they are never eliminated entirely. Prior to age 25, the death rate among white females is greater.

Tuberculosis and economic status. — While tuberculosis does not respect race, religion, color, education, or social status, afflicting both rich and poor, great and humble, powerful and weak, it is true that the death rate in the poorer economic groups is greater than among those of superior economic status. This is not surprising, as the more well-to-do usually experience fewer industrial hazards and are able to live more hygienically. Dublin* points out that among white males between ages 15 to 74 who were insured in the Industrial Department of the Metropolitan Life Insurance Company, the death rate from tuberculosis, all forms, per 100,000 persons was 136.6. On the other hand, the death rate from tuberculosis among all males in the same age group who were insured in the Intermediate Branch Department was 108.0, while the rate for all males in the same age group, insured in the Ordinary Department, was only 61.5. These three groups represent different economic levels in ascending order. An analysis of the death rates among these three groups by smaller age groups shows the same differences, at age 35 to 44, the rates being 187.1, 103.1, and 63.7, respectively. Data are also available to show that the more well-to-do Jews of New York living under desirable housing conditions, exhibit lower death rates from tuberculosis than the Jews who reside under conditions of poverty and congestion. Poverty and ignorance have always taken their toll of human life, and in tuberculosis. they play an especially important rôle.

Tuberculosis and occupation. — That occupation is an important factor in determining the incidence and mortality from tuberculosis is evident from an analysis of the morbidity and mortality data for tuberculosis by occupations, and a comparison of the resulting rates.

In spite of various handicaps introduced by the complexity of the problem such as race, color, age, economic status, etc., definite information on this subject has been obtained. For example, among

* Louis I. Dublin, *Health and Wealth*, Harper & Bros., 1928.

males between 25 and 65, farm laborers, farm servants, locomotive engineers, stokers and cleaners, motor car and motor van drivers, and builders have comparatively low death rates from tuberculosis. At the other end of the scale, however, are tin miners, cutlery makers, file makers, stone workers, lead miners, pottery and earthenware workers, brass and bronze workers, shoemakers and printers, all of whom exhibit mortality rates from tuberculosis from three to twelve times as high as are found among those in the first list of occupations. It is evident that working in dusty, poorly ventilated quarters where the air is laden with particles of metal, stone, sand, cotton, and wool is especially conducive to the development of tuberculosis.

The prevention of tuberculosis in industry is one of the pressing problems of Industrial Hygiene, requiring the application of nearly all the hygienic and sanitary arts and cannot of necessity be thoroughly treated here.

Tuberculosis and color. — If tuberculosis is a significant disease among the white population of the United States, it is a decimating disease among negroes. The problem of tuberculosis presented by the colored population is one of the major public health problems in the United States and is doubtless equally serious in all countries where the negro population is large. Its significance is enhanced because negroes are frequently employed as nursemaids, house servants, waiters, and in other occupations which permit easy contact between the races. In the United States the tuberculosis death rate among negroes is from 3 to 8 times as high as that among whites. While rates of 50 to 100 may prevail for the white population of a community, rates as high as 300 to 400 may prevail among the negroes in the same community. Furthermore, while the death rate from tuberculosis among whites has been diminishing consistently, the death rate from tuberculosis among negroes has fluctuated widely during the same period. This is illustrated by the data from Detroit which are presented in Table 40 on page 477.

Of even greater significance is the analysis of the death rate from tuberculosis by age, sex, and color simultaneously. Thus it is found that the death rate among the colored is higher for each age group than the corresponding rate among the whites. The tuberculosis death rate among the colored males reaches its peak at ages 20 to 24, while for white males, the peak is not reached until ages 45 to 54. Both white and colored females experience

TABLE 40

DEATH RATES FROM TUBERCULOSIS, ALL FORMS, PER 100,000 POPULATION FOR DETROIT, 1923 1932, DISTRIBUTED ACCORDING TO COLOR *

YEAR	WHITE	COLORED
1923	83.7	272
1924	85.8	312
1925	72.0	355
1926	75.0	353
1927	70.0	380
1928	68.2	447
1929	66.0	441
1930	57.3	398
1931	51.7	338
1932	50.3	312

their highest tuberculosis death rate in the same age group, 20 to 24, but the death rate among colored females is very much higher than among white females.

Tuberculosis and geographical distribution. — Tuberculosis is a universal disease, but exhibits marked variations. In the United States, its distribution as judged by prevailing mortality rates is especially low in the essentially rural states while it is strikingly high in those states where the proportion of negroes to the total population is appreciable. The highly urbanized industrial states occupy a middle ground. Thus the states showing extremely low death rates from tuberculosis are Utah, Wyoming, Nebraska, Idaho, Kansas, North and South Dakota, and Montana, while the states showing the highest death rates from this disease are Alabama, Mississippi, Louisiana, Virginia, Maryland, Kentucky, and Tennessee. The death rates from tuberculosis are also high in California and Colorado, but as both of these states annually receive thousands of tuberculous patients who come from other parts of the country for treatment, the high death rates are explainable on this basis alone.

Until recent years the death rate from tuberculosis among the rural residents in each state was considerably lower than that which prevailed among the urban residents. This difference has largely or completely disappeared as a result of the ease of communication and the rapidly vanishing distinctions between rural and urban communities. Furthermore, the superior health protection provided in urban communities has eliminated some of

* *Annual Report*, Detroit Health Department, 1932.

the disadvantages of the attendant congestion. Tuberculosis has always followed concentration and the development of towns and cities. It was and still is comparatively rare among the dwellers of the mountains or the prairies, but as has been shown, many cities are now as safe from tuberculosis as life in the rural regions has been in the past.

Reporting of tuberculosis. — The campaign against tuberculosis can be waged successfully only by bringing every case to the attention of the recognized health authorities as early in the disease as possible, and by placing such cases under suitable treatment for an adequate period of time. This necessitates the early recognition and prompt reporting of all cases of tuberculosis. Without such assistance the methods of prevention and control lose in effectiveness. The system of compulsory reporting of cases of communicable disease bears a relationship to the health department which the fire alarm system bears to a city fire department. In each case the report is a signal to marshal the community forces against the unwelcome invader.

Although tuberculosis was responsible for so much illness and death, it was not until 1893 that it was made a reportable disease. In that year, one of the distinguished pioneers in public health work in the United States, Dr. Herman M. Biggs, succeeded in making compulsory the reporting of all cases of tuberculosis occurring in the public institutions of New York City, but as the time was not considered propitious to require physicians in private practice to do likewise, reporting of cases of tuberculosis by them was made purely voluntary. In 1897, however, the reporting of cases of tuberculosis in New York City was made compulsory both for public and private patients. Since then, tuberculosis has become a reportable disease throughout the United States.

By its very nature, tuberculosis is still a poorly reported disease. In the Framingham Tuberculosis Demonstration where a careful examination of the residents was made, it was found that there were nine active cases for every death from tuberculosis. Although this ratio of cases to deaths must be considered conservative in the light of the progress made in the diagnosis of early tuberculosis since the Framingham Tuberculosis Demonstration was held, there is not a city in the United States that approaches this standard. In 1930 Boston reported 2,016 cases and 604 deaths from tuberculosis, a ratio of 3.1 cases per death. In 1932, the ratio of cases

to deaths in Detroit was 3.3 to 1. In Massachusetts for 1932, the ratio of reported cases of pulmonary tuberculosis to deaths from the same cause was only 1.95 to 1. It is evident, therefore, that tuberculosis is not being adequately reported, and unfortunately, this situation is not improving, so that the outlook for the early recognition and prompt reporting of cases of tuberculosis is not highly encouraging. In fact, in 1932, 15 per cent of all cases of pulmonary tuberculosis reported in Massachusetts were not brought to the attention of the health authorities until after the death certificate had been filed. It was also found that 25 per cent of all cases of pulmonary tuberculosis are dead within six months after they are reported and that 75 per cent of the fatal cases are reported less than six months prior to death. In a more detailed analysis of the reporting of pulmonary tuberculosis in Boston made for the year 1923, Horwood reported that about 20 per cent of all the deaths from pulmonary tuberculosis had never been reported as living cases, and that in over 36 per cent of the deaths reported, only one month elapsed between the reporting of the case and the filing of the death certificate. What thus seems like a lack of cooperation on the part of the medical profession is due in part at least to the inability of the average physician to diagnose early tuberculosis, a fact which is supported by the evidence that most physicians still wait for a positive sputum before making a diagnosis. Unfortunately tuberculosis is a reasonably advanced disease when this condition prevails, and the opportunity for successful treatment is much lessened.

Finding the early case of tuberculosis. — Even in the early days of the anti-tuberculosis campaign, it was recognized that the most hopeful attack lay in locating the incipient case of tuberculosis and placing it under suitable sanatorium care. When sanatoria were first established there were so many open, active cases of tuberculosis constantly discharging tubercle bacilli and in daily intimate contact with other members of their families, that the greatest need was for removal from the home and isolation in institutions. As this need was met more adequately by gradually expanding hospital and sanatorium facilities, greater emphasis was placed on the location of the early and favorable case and its proper hospitalization. This led to the development of tuberculosis clinics, to the examination of contact cases, to the construction of municipal, county, and state sanatoria, and to the

conduct of educational campaigns urging individuals to be examined at the public clinics or privately by a competent chest diagnostician. The early case is the hopeful, salvable case. Hence the emphasis on its detection and prompt treatment.

Moreover, the so-called pre-tuberculous case soon came to be recognized. These are represented by the contact cases, by children who are markedly underweight and poorly nourished, and by those individuals who are ailing constantly for no obvious reason. For such individuals, open air classes and schools were organized, special nutrition classes were established in the schools, summer camps and preventoria were developed, and a whole gamut of activities was initiated to further the effectiveness of these agencies. Since it is now generally recognized that tuberculosis is a struggle between the infection and the vital resistance of the individual, any factor that increases his resistance operates either for the prevention or the control of the disease. In pulmonary tuberculosis the infection occurs in the apex of the lung. Here the organisms establish themselves in the alveolar tissue and slowly destroy it. If the host has sufficient resistance the organisms will be walled off by fibrosis and calcification, so that the infection cannot proceed any further. If the resistance of the host is low, his defenses will be insufficient to overcome the infection and the destruction of tissue will continue practically without restraint.

Factors affecting vital resistance. — The factors that affect the vital resistance of the individual are many and varied. Primarily they include the items normally listed under personal hygiene and some others. These comprise, for example, a satisfactory and adequate diet, plenty of fresh air, access to sunlight, open air recreation, ample rest and refreshing sleep, proper elimination of body wastes, bathing, suitable hand and oral cleanliness, avoidance of excess fatigue, unnecessary exposure to inclement weather, and freedom from worry and nervous strain. To these should be added avoidance of alcoholism, avoidance of crowds, and of living under congested and unsatisfactory housing conditions. In addition, all places of employment should have a proper conditioned atmosphere, free of injurious industrial dusts. Other requirements are the early discovery and prompt elimination of physical defects such as enlarged tonsils and adenoids, defective teeth, etc., freedom from debilitating diseases such as measles, scarlet fever, diphtheria, whooping cough, pneumonia, influenza, adenitis, etc., proper pos-

ture, freedom from infected food and insects capable of transmitting disease, and doubtless many other factors not enumerated here. It is evident that tuberculosis is related to all aspects of human life. Anything that advances the elimination of disease and the development of one's vital resistance, aids in the control of tuberculosis.

Reasons for reduction in tuberculosis mortality. — The explanation of the marked reduction in tuberculosis mortality that has occurred since the discovery of the tubercle bacillus is still a debatable question among students of public health problems. Some believe that tuberculosis mortality had begun to decline prior to the discovery of the tubercle bacillus and that the reduction which has occurred is simply a phase in the biology of an important disease. Others maintain that the decline in tuberculosis mortality is due to the cumulative beneficial effects of numerous factors all of which have contributed to build up the vital resistance of the individual and to protect him against many debilitating diseases. Among these must be mentioned the marked improvement in the standard of living witnessed in the United States particularly, the elimination of long hours of employment, the introduction of machinery to replace muscle in the conduct of laborious work, thus eliminating excessive fatigue; better and more adequate nutrition, the conquest of typhoid fever, the pasteurization of milk, the protection of water supplies, the construction of sewerage systems, the universal availability of plumbing facilities, the improvement in housing conditions, the detection and elimination of physical defects, the extensive campaign of popular and personal health education, the initiation of vacations and shorter work weeks, and the masterly control of the environment and its agencies for the transmission of disease and the reduction in vital resistance. These conditions are permanent improvements to the art and science of living, the result of man's own efforts. Hence the progress against tuberculosis must be regarded as human in origin and not merely a biological phenomenon.

Prevalence of tuberculous infection as indicated by autopsy findings. — In 1900 Nägeli performed autopsies of all deaths occurring at a large general hospital in Zurich, Switzerland, and found evidence of tuberculosis in 97 per cent of the individuals examined. As late as October, 1917, this observation could still be confirmed, and it may be true even today. It indicates the extent

to which tuberculous infection has invaded the general population. Happily more people resist its incursions than die from the disease, although it is a lingering one and individuals may have it for 10, 15, and even 20 years. It is evident, therefore, that the sooner tuberculosis is discovered in the individual and brought under control, the more effective will be the campaign against it.

Means for the early detection of tuberculosis. — Application of the extension of our knowledge of the epidemiology of tuberculosis during the past ten years has not only made it possible to reduce the death rate, but to indicate a new method of attack for its further conquest. By means of the tuberculin reaction, usually referred to as the von Pirquet or the Mantoux tests, the presence of tuberculous infection can be determined. The tuberculin that is used is known as Old Tuberculin and was first developed by Koch in 1890. It contains neither living nor dead tubercle bacilli, but consists of the products of tubercle bacilli which have been grown in a broth culture, filtered through porcelain filters and then boiled down to half its original volume. Koch thought he could use this tuberculin to develop immunity against tuberculosis. This was not successful, but the product has distinct value in ascertaining the presence or absence of tuberculous infection through the skin reactions which it activates.

In attempting to determine the presence of tuberculous infection in apparently healthy children, the von Pirquet test has proved more reliable and practicable than the Mantoux test. The latter is an intradermal test and is performed with the aid of a hypodermic needle. The von Pirquet test is a cutaneous test made by scarifying or gently scratching the skin with an instrument resembling a jeweler's screwdriver. The outer layer of skin is rubbed off, the tuberculin is applied, and the scarification performed. There is no bleeding, no fever, and no pain. At the end of 3 to 5 days the reaction is read, and if there is a slight redness with swelling, like that following a mosquito bite, the reaction is positive.

When the von Pirquet tuberculin reaction is applied to apparently healthy children it is possible to segregate those who have active infection from those who have healed infections. Dr. Alton S. Pope in Massachusetts found that about 20 per cent of the children who gave a positive von Pirquet reaction became negative after a few years, presumably as a result of the virtual elimination of tuberculous infection. We have therefore in this

test, a powerful tool by which it is possible to determine the presence of active infection in apparently healthy individuals long before the disease itself becomes clinically manifest.

Another weapon developed during the past ten years in the fight against tuberculosis is the X-ray examination. By this means it is possible to detect the earliest presence of tuberculous lesions, the so-called childhood or hilum or tracheo-bronchial type of tuberculosis. This type of tuberculosis, which is benign, is free of clinical symptoms, and invariably heals; but it is always the precursor of the adult or pulmonary type of tuberculosis. In the small group of school children exhibiting childhood tuberculosis, which represented from 1 to 4 per cent of the school child population examined, Myers found that they contributed from 50 to 60 per cent of all the pulmonary tuberculosis occurring in childhood. It is now believed that the development of active pulmonary tuberculosis is not due to a further development of the tuberculous infection obtained in early childhood, but rather due to a secondary infection received after childhood tuberculosis has occurred. This is a significant change in our knowledge of the epidemiology of tuberculosis. It indicates the importance of finding all cases of childhood tuberculosis as promptly as possible, applying effective treatment, and preventing further infection with tubercle bacilli if the disease is to be controlled. Hence the importance of the X-ray in conjunction with the von Pirquet test in the detection of the childhood type of tuberculosis. The X-ray is also valuable in tuberculosis control, since its use makes it possible to trace the progress of the disease in the chest and to distinguish the healed from the active lesions.

Tuberculosis and inheritance. — Tuberculosis has always been recognized as a *family* disease, and because of its universal prevalence it is not surprising that it was long regarded as an hereditary ailment. In days past, certain areas were designated as "tuberculosis nests," and certain city blocks as "lung blocks." Even the very house or apartment occupied by a terminal case of tuberculosis was supposed to be infective. In the early days of the anti-tuberculosis crusade, official and voluntary health agencies interested in the control of tuberculosis provided fumigating facilities for thoroughly "disinfecting" the rooms which had been occupied by a case of fatal tuberculosis. Pungent, obnoxious, and suffocating gases, assumed to have high germicidal value,

were released. The health official, possibly with a sense of self-righteousness and high public performance, assumed that a professional duty had been well done. In the light of present knowledge it is highly probable that very little good was actually accomplished. Fumigation has now been abandoned, and in its place the liberal use of hot water and soap, fresh air and sunshine, has been substituted to render safe the habitation vacated by the tuberculosis victim. Unlike many infectious diseases, tuberculosis is not spread to any appreciable degree through the environment. It is spread primarily by contact infections derived from living cases of tuberculosis.

Therefore, today, tuberculosis is not regarded as an hereditary disease although its occurrence in families is recognized. The new-born infant is seldom if ever born tuberculous, even if the mother is seriously suffering with tuberculosis. In view of the daily contact in early life the chances of a tuberculous infection in childhood are obviously much greater if one or both parents are tuberculous, than if the parents are free from the disease. It is also possible that the child of tuberculous parents may have a weakened or frail constitution and thus be physically predisposed to the disease. Infection means, then, not that the disease itself is inherited, but that the factors of lowered vitality and constant exposure combine to bring it about.

The ultimate fate of children exposed to infection in the home varies with the age at which real infection occurs. A large proportion of the infants who become infected and who, as a result, react positively to tuberculin, die of tuberculosis. But we must now distinguish between infection as shown by test, and disease as manifest by clinical symptoms. Over 80 per cent of the children exposed in the home become infected during the first five years of life. In the Massachusetts study of children of school age (5 to 19), it was found that tuberculous *infection* was twice as frequent among contact cases as among non-contact children, while tuberculous *disease* was 7 to 8 times as frequent among the contact children. This illustrates the great seriousness of daily contact with active cases of tuberculosis in the home. Nevertheless, between the ages of 5 and 15 years, tuberculosis among contact children tends to pursue a benign, *i.e.*, non-malignant, course. Toward the end of this age period about 25 per cent of the children develop the clinical symptoms of tuberculosis, with loss of weight and impaired health, and

become frank cases of pulmonary tuberculosis. The significance of the period of adolescence in the development of tuberculous disease has already been emphasized and the outlook for young females suffering from pulmonary tuberculosis during adolescence is particularly discouraging.

Recent investigations in childhood tuberculosis. — For the recent progress made in our knowledge of the epidemiology of tuberculosis the world is indebted especially to two groups of health workers: The Massachusetts Department of Public Health, which in 1924, inaugurated a ten-year childhood tuberculosis program; and Dr. Eugene L. Opie, formerly of the Henry Phipps Institute for Tuberculosis Research in Philadelphia, and his associates. Both groups have studied the problem of childhood tuberculosis independently and exhaustively. Other studies were conducted in New York City, in Cattaraugus County, N.Y., in Detroit, and in the states of Tennessee, Alabama, South Carolina, Florida, Mississippi, Minnesota, and Montana. A brief presentation of some of the findings is therefore of timely interest.

In Massachusetts, from 1924 to 1932, a total of 275,252 children between the ages of 5 and 19 were examined by means of the von Pirquet reaction, and of this number, 69,049, or approximately 25 per cent, gave positive reactions. The children examined were apparently healthy, comprised both contacts and non-contacts, and represented a great range of racial stocks and socio-economic conditions. Tuberculous infection occurred with the same frequency in both sexes, but tuberculous disease occurred more frequently among girls at all ages during this period and invariably in more serious form. For the group as a whole the tuberculosis morbidity rate for girls was 40 per cent higher than for boys. As the children advanced in age tuberculous disease increased in frequency, but for each age group the tuberculosis morbidity rate for girls was higher than for boys.

Among the contact children tuberculous infection as determined by the tuberculin reaction occurred with equal frequency in both sexes. As the age of the contacts increased there was a simultaneous increase in the proportion of reactors. Furthermore, the data showed that the existence of tuberculosis in one or both parents is more often associated with tuberculous infection in the contact children than when another member of the family is affected. Among the contact children familial infection seems to

be of equal danger to both sexes whether the yardstick of measurement be in terms of frequency of infection, frequency of tuberculous disease, or frequency of frank pulmonary tuberculosis. The absence of a differential tuberculosis morbidity by sex among contact children is thus in direct contrast to the generally greater susceptibility to tuberculosis of female children as a whole. This is explainable on the basis that familial contact is associated with prolonged and heavy infection to an extent, it is believed, sufficient to overcome any greater relative resistance which boys in this age group may possess.

Defining underweight as being 10 per cent or more below the standard weight for age and sex, the Massachusetts studies showed that tuberculous infection occurs practically with equal frequency among the normal weight and the underweight children. This is true for both males and females and for contacts and non-contacts. On the other hand, the tuberculosis morbidity rates were consistently higher for the underweight children than for the children of normal weight; and extreme underweight, *i.e.*, 15 per cent or more underweight, was definitely associated with a generally higher specific tuberculosis morbidity. In spite of the correlation that seems to exist between underweight in children and the development of tuberculous disease, it should be expressly understood that underweight in children is in itself no indication of the prevalence of tuberculous disease and that the absence of an underweight condition does not exclude the possibility of tuberculosis.*

From 1924 to 1932, as part of the Massachusetts Childhood Tuberculosis Campaign, 74,107 school children between the ages of 5 and 19 were given X-ray examinations. Of this number, 3,898 or 1.4 per cent were found to have childhood tuberculosis, and 203 or 0.07 per cent, the adult or pulmonary form of tuberculosis. In addition, there were 10,174 children or 13.7 per cent who were classified as suspects. The incidence of pulmonary tuberculosis in high school children was found to be six times greater than the rate among children in the primary grades.

The incidence of tuberculous infection as measured by the tuberculin reaction varies within astonishingly wide limits in different parts of the United States. Taking the reaction at age 15

* The above summary of the Massachusetts findings was obtained from the analysis prepared by Dr. E. P. Hutchinson in 1933 for his Doctor's degree at the Massachusetts Institute of Technology.

as an index of the frequency of infection acquired during earlier childhood, Opie presents the following data. In Philadelphia, 77 per cent of the white children and 83 per cent of the colored children in the public schools gave a positive tuberculin reaction. In New York, 70.4 per cent of the children examined gave a positive reaction. In a suburban district near Boston, approximately 52 per cent of the children at age 15 reacted, although for Massachusetts as a whole, only 35 per cent reacted at age 14. In Cattaraugus County, N.Y., a rural district, only 16 per cent of the white children reacted at age 15. In certain rural districts of the south, and at the same age, 65 per cent of the white children and 73 per cent of the colored children reacted. In Alabama, Florida, Mississippi, and South Carolina, from 58 to 68 per cent of the colored children examined gave a positive reaction at age 15. In the rural districts of Minnesota only 12 per cent of the white children reacted at age 15, while in Montana the reaction rates for white children were 24.2 per cent and for full blooded Indian children, 70.4 per cent.

These studies demonstrate clearly that tuberculous infection in childhood occurs with great frequency, and that in general it is more widespread in urban than in rural communities. A negative tuberculin reaction invariably indicates the absence of an active infection, but for those who show a positive reaction, the X-ray should be employed to ascertain the existence or absence of recognizable tuberculous disease. Those showing signs of childhood tuberculosis should be placed under effective treatment in order to prevent the development of the more serious form, namely, pulmonary tuberculosis.

The prevention of tuberculosis. — Enough has been said in the preceding sections to indicate the magnitude of the tuberculosis problem, the methods that are currently employed to detect tuberculous infection and childhood tuberculosis, and the importance of preventing the development of "adult" tuberculosis. The program of prevention must necessarily be wide in scope and highly effective if the campaign is to be reasonably successful. Under the best conditions the difficulties will be numerous and in many instances almost insurmountable. All frank, open cases of pulmonary tuberculosis should be identified and removed from the home in order to protect the contact cases. This in itself is a gigantic undertaking, difficult of attainment. Children who

show evidence of childhood tuberculosis should be treated in well-supervised sanatoria or in carefully selected preventoria where the supervision is excellent.

For children who show tuberculous infection but not tuberculous disease, and for others who are pre-tuberculous, open air classes, open air schools, summer health camps, and preventoria may be employed. In the conduct of these activities the emphasis should be placed primarily on building up the vital resistance. This means strict adherence to the rules of good personal hygiene. All physical defects, including enlarged tonsils and adenoids and dental caries should be detected and corrected. Children should also be immunized against diphtheria and smallpox. A well-balanced diet, adequate in amount, with particular emphasis on mineral and vitamin sufficiency should be insured. Proper elimination should be practised. There should be sufficient emphasis on adequate rest and sleep, and care should be taken to avoid undue fatigue and strenuous exercise or sports. Children should have ample exposure to fresh air and sunshine, but exposure to colds and drafts, particularly during cold weather, should be avoided. The parents as well as the children should receive instruction in the principles of healthy living, for without parental assistance and guidance, much of the value of the preventive measures will be wasted. Finally, there must be adequate expert medical and nursing supervision for each child, so that his progress can be followed intelligently, and any necessary change in treatment instituted in ample time. Emphasis should also be placed on the use of pasteurized milk, a pure water supply, proper sewage and garbage disposal facilities, personal cleanliness, and protection against flies and mosquitoes.

The first open air school was established at Charlottenburg, near Berlin, in 1904. Since then open air classes or schools have increased rapidly. In 1926 there were at least 1,006 open air schools in 245 cities in the United States which cared for 32,064 pupils. Undue emphasis has often been placed in the prevention or treatment of tuberculosis on the value of being actually out-of-doors. Happily, a more rational distinction between the value of fresh air and undue exposure has developed in recent years, resulting in greater emphasis on the more significant hygienic practices such as nutrition and rest. The late Dr. John A. Ceconi, Director of School Hygiene for the Boston Public Schools, in

accord with a recommendation of the *Boston Tuberculosis Survey Report of 1925*, provided extra nourishment, rest, and medical and nursing supervision during the school day for all pre-tuberculous children without segregating them into special classes. The recess and luncheon periods which normal children utilize largely for exercise, were reserved as rest periods for the pre-tuberculous children. Cots and blankets were provided and the children were served luncheon in school under supervision. A mid-morning and mid-afternoon luncheon was also served. Each child paid for the cost of the food, and for those children too poor to pay, the assistance of various charitable agencies was enlisted. In many respects this plan proved more workable than the customary open air class or open air school.

Summer health camps for pre-tuberculous children have become favorite activities of local tuberculosis associations in various parts of the country. In Massachusetts, where the general health program developed by the State Department of Public Health is remarkably effective, the local tuberculosis associations have organized summer health camps for pre-tuberculous children on an extensive scale. Outstanding among these are the camps operated by the Boston and Cambridge Tuberculosis Associations. The children are carefully selected according to history of tuberculosis exposure and general physical condition, and are then subjected for a period of one to two months to a carefully supervised, scientific régime designed to build up resistance to tuberculosis. All of the previously cited suggestions for the effective prevention of tuberculosis are rigidly followed. These camps are excellent illustrations of the intelligent, public spirited community effort that is being made in the United States to aid in the prevention and control of tuberculosis.

In addition to the summer health camp, the preventorium has come into existence as an agency in the prevention of tuberculosis. The preventorium is an all year round institution designed for the care and treatment of pre-tuberculous children. In 1930 there were 32 preventoria in the United States with accommodations for 1,600 children. In addition, there were 57 preventorium units associated with tuberculosis sanatoria which could take care of 3,400 children. Reference may be made to the excellent Prendergast Preventorium operated by the Boston Tuberculosis Association, as an example of what such an institution should be.

The foregoing are specific instrumentalities for the prevention of tuberculosis. There are, however, other public health activities, not conducted primarily to prevent tuberculosis, but which can have a profound influence toward this end. For example, there are numerous infant welfare and preschool child clinics in the United States where expert medical service, aided by the von Pirquet test and the X-ray picture when necessary, and a careful family history, could detect many cases of tuberculous infection and of childhood tuberculosis and bring them to the attention of the recognized agencies for the prevention of tuberculosis. In addition such clinics can disseminate valuable information concerning proper nutrition, the elimination of physical defects, the protection against childhood diseases, and the principles of healthy living. During the school period children are again subjected to medical examinations, nursing follow-up work, and health education. If these activities are conducted effectively, much can be done to inculcate a knowledge of the requirements of healthy living and to detect all pre-tuberculous, infected, and diseased children, and to guide them to suitable treatment. This campaign should be extended into the high school group at least, in order to cope more effectively with the serious problem of tuberculosis in adolescence. Furthermore, when children leave school to seek employment, they should be examined for tuberculosis and other ailments in order to avoid serious impairment of health during adult life.

The problem of tuberculosis in adult life has been a pressing one for a long time. Tuberculosis clinics, sanatoria, and hospitals are available in every state. In addition, industry has undertaken important measures of prevention, sometimes voluntary and sometimes due to Federal or state legislation. Employees are sometimes examined to determine physical fitness for certain types of work. Hours of employment are fixed by law; minimum wages are specified; industrial hazards, including industrial dusts, are required by law to be eliminated; heating, lighting, ventilation, hand washing facilities, drinking facilities, toilet facilities, and other sanitary safeguards are also usually required; and in addition there may be lunch room facilities, nursing service, and other aids to protect and promote the health of the employee.

Besides the direct anti-tuberculosis activities already enumerated and discussed, there are other public health practices which

are valuable in the prevention or control of tuberculosis. Included among these are the following: the sanitary production and pasteurization of milk and dairy products; popular health education through the press, the radio, the moving picture, the stereopticon, the poster, the exhibit, the lecture, the demonstration, and special bulletins and leaflets; the sanitary protection of all food supplies and food service; the detection and control of tuberculous food handlers and nursemaids; the improvement of housing conditions; the elimination or control of congestion; the provision of parks and playgrounds; and the control of smoke and dust. In most of the larger cities in the United States, pure water and adequate sewerage have been provided. Where such are not available, they should be provided in order to avoid debilitating disease which may pave the way for tuberculosis, and to promote personal and environmental cleanliness.

Modes of infection in tuberculosis. — Without the tubercle bacillus there can be no tuberculosis. Therefore, in order to prevent the disease it is necessary to know how tuberculous infection is spread. Tuberculosis is acquired primarily through the respiratory tract or by ingestion. Ingestion infection may occur through the use of infected milk and dairy products, through infected meat, or through food infected in preparation or handling. The elimination of tuberculous cows by means of the tuberculin test, and the widespread use of pasteurization for milk and dairy products in the United States, has largely eliminated the dangers of bovine tuberculosis to man. The careful ante-mortem and post-mortem examination of all food animals shipped in interstate commerce has also helped to control tuberculosis of animal origin in man. Since meat and meat products are cooked before eating, the danger of infection from these sources is further reduced. The protection of food and eating utensils against infection in public eating places can be accomplished in part by excluding tuberculous food handlers. Although infection theoretically may be acquired in public eating places, in practice it is not very probable, and in comparison to other methods of infection, must be considered of minor importance.

Tuberculous infection is primarily of human origin and is transmitted from one individual to another principally by contact. Aërogenic infection, dust infection, infection through fomites may and probably do occur, but they are insignificant compared to

contact infection. Kissing, droplet infection, fresh and frequent infection through the use of the hands, the common glass or drinking cup, the promiscuous use of eating utensils without proper sterilization in families where an active case of tuberculosis exists, the improper disposal of tuberculous sputum, the common use of handkerchiefs or towels infected with tubercle bacilli, spitting, the improper protection of the tuberculous cough, loud speaking, sneezing, moistening the fingers with saliva to turn the pages of a book or to distribute transfer tickets, the licking and subsequent application of postage stamps to envelopes, these are some of the methods by which infectious material in the saliva and sputum is transmitted by contact. True, the germs of disease do not live very long in the environment, but the tubercle bacillus is a hardy pathogen, and even if some die, a fresh supply may soon replace them. Flies may also play a part in the transmission of tuberculous infection, but in this horseless era, flies are no longer numerous in most places, and their significance as vehicles of disease has thus been greatly reduced.

Preventive treatment by the use of BCG. — In view of the success that has attended the use of biological products for preventing such diseases as smallpox, diphtheria, and typhoid fever, it is not surprising that a similar agent has been sought against tuberculosis. Koch developed his tuberculin in the belief that it would accomplish this end, but experience proved otherwise. Other products also failed. Even early tuberculous infection and childhood tuberculosis do not protect the individual against the later development of pulmonary tuberculosis. The most hopeful biological agent as yet developed for the immunization of the human against tuberculosis is the BCG culture treatment. This refers to the use of a specific strain of the tubercle bacillus, known as Bacillus Calmette-Guérin, named after the two distinguished workers of the Pasteur Institute in Paris (Calmette died in 1933), who maintain that the organism has lost all of its toxic properties and can no longer produce tuberculosis. The culture used is a growth of living bacteria originally made by cultivating this special strain of tubercle bacilli continuously during thirteen years on a medium containing ox-bile. More than two hundred successive transplants were used. The French workers claim that this culture is not only avirulent for man, but also for domestic animals and fowl. In spite of its lack of virulence, it is supposed

to stimulate the production of anti-bodies against tuberculosis. It is administered orally. Prophylactic treatment is begun in infancy, soon after birth, before the child becomes infected from human sources, a definite amount of the culture being administered on the third, fifth, and seventh day. Apparently the infant experiences no unfavorable effect.

The system of immunization has been widely practised in France and in the French colonial possessions, but has not been used extensively in any other country. It is maintained that the death rate from tuberculosis among infants has been reduced from 25 per cent to 2 per cent. In the United States it has been employed experimentally by Dr. W. H. Park of New York with favorable early results. The question of its efficacy is still unsettled and the ultimate verdict must await more universal experience.

The tuberculosis clinic. — What is now known as the tuberculosis clinic had its inception in Edinburgh in 1887 when the Victoria Dispensary was established. Since then clinics have multiplied rapidly everywhere. In the United States they were first organized by charitable and welfare agencies, or by local branches of the National Tuberculosis Association. Later, these were taken over to a large extent by the state or local boards of health and operated as a regular public health activity. At present such clinics are conducted by health departments, tuberculosis associations, out-patient departments of hospitals, health centers, and private dispensaries. In addition, expert consultant diagnostic service is rendered in many places by medical experts associated with state, county, and local tuberculosis sanatoria.

The tuberculosis clinic has long been the first line of defense in the community campaign against tuberculosis. Its success in this direction is in direct proportion to the extent to which early and favorable cases of tuberculosis are discovered and placed under effective sanatorium treatment, as previously discussed. In order to render most effective service in the large city, clinics should be decentralized, *i.e.*, located in various sections so that they are easily accessible to all the inhabitants.

Another essential requirement for effective clinic service is the presence of expert diagnosticians. Without such medical aid the clinic loses much of its value. Experts in the diagnosis and treatment of tuberculosis of necessity must have post-graduate special-

ized training, and only such well-equipped physicians should be appointed to serve at a tuberculosis clinic.

The tuberculosis nurse or the public health nurse associated with the tuberculosis clinic is another salient element in its successful conduct. On her depends the extent to which contact cases and new cases are attracted to the clinic for examination. She is responsible, too, for the education of the patient and the family in the proper care of the sputum, and the importance of using separate dishes and eating utensils and their subsequent sterilization. She should teach the patient and family the essentials of an adequate and well-balanced diet, and she must instruct the patient in the essential phases of good personal hygiene. Often she must help the family to solve social and economic problems, the success of which will affect the progress of the patient. She must be the sympathetic, interested, helpful friend of the family and serve as the human link between them and the clinic physician and community. When sanatorium or preventorium treatment is available, she must use her influence and persuasiveness to convince the patient to accept the necessary treatment, and she must supervise the actual transfer of the patient to the institution. She must make the tuberculosis clinic attractive, aid the physician in taking case histories, assist in the examinations, and provide printed educational material at the clinic and in the home.

In the present state of the tuberculosis problem, work with children alone will not suffice to bring the disease under control. The active case of adult pulmonary tuberculosis must be discovered and removed to a sanatorium where he ceases to be a source of infection to other members of his household and where he may receive effective treatment. This necessitates entering business and industry in order to urge people to come to the clinic for examination. The popular campaign which has been waged urging people to have an annual medical examination is not enough. The contact must be human and convincing, and it must reach those individuals whom the popular campaign in the press or over the radio does not touch. The establishment of night clinics, especially in districts inhabitated by the industrially employed, is a great aid in finding cases among this portion of the population. Special attention should also be given to the more effective control of tuberculosis in adolescence and early adult life, particularly

among females. According to the Committee on Administrative Practice of the American Public Health Association, there should be a minimum of 1,500 clinic visits in a community for every 100 deaths from tuberculosis per annum. The Committee also suggests that a tuberculosis clinic physician should not be required to see more than 10 patients during a two-hour period.

Tuberculosis hospitals and sanatoria. — The tuberculosis hospital and sanatorium occupy a recognized and important part in the campaign against tuberculosis. The first sanatorium in the United States was opened at Saranac Lake, N.Y., in 1884 by Edward L. Trudeau, the famous physician, who had gone to the Adirondacks to recover his health after tuberculosis set in. The story of this pioneer and his work in the mountain village and the inspiration which he gave unconsciously to others in all parts of the civilized world, is a remarkable chapter in the history of medicine as well as the anti-tuberculosis movement. The Sharon Sanatorium at Sharon, Mass., was the second to be established in the United States. A little later came the State Tuberculosis Hospital at Rutland, Mass., and the many others in all quarters of the United States, organized by states, counties, cities, and private organizations. In Massachusetts in 1933 there were four tuberculosis sanatoria operated by the State Department of Public Health, eight county sanatoria, and numerous municipal and private institutions.

The increase in the number of tuberculosis sanatoria in the United States is indicated further by the increase in the number of beds available for tuberculous patients. In 1904, there were 10,000 sanatorium beds; in 1910, 26,000; in 1922, the number was approximately 70,000; and in 1933, it was well over 100,000. It is estimated that two sanatorium beds ought to be available for each annual death from tuberculosis, the number of deaths being determined by averaging the deaths from tuberculosis over the previous five-year period. In 1933, there were available in Massachusetts, 1.8 beds for each annual death from tuberculosis, an unusually high attainment.

The tuberculosis sanatorium is potentially one of the most effective community weapons against tuberculosis. Here the active case may be placed under effective medical and nursing supervision. Here he may learn the meaning of rest, of proper diet, of proper care of the sputum, and the essentials of hygienic living.

Here, besides the advantages of expert medical and nursing care, he has the X-ray, the laboratory, the nose and throat specialist, the dentist, the occupational therapist, and the social service worker at his disposal. The sanatorium is potentially able not only to cure and arrest tuberculosis, but it has the power to salvage the individual mentally as well as physically, and to return him once more to society as a self-respecting wage earner.

Unfortunately, the sanatoria and tuberculosis hospitals have not attained their fullest potentiality in the past. Sometimes they have been administered poorly and politically, without sufficient emphasis on the requirements of scientific treatment, and in such cases they have served mainly to provide free board and lodging for certain unfortunates in the community. The fullest cooperation of patients, which is so essential in the successful treatment of tuberculosis, is usually lacking in such instances, and these institutions develop an unfavorable reputation which keeps respectable citizens away, thus hampering the community in its efforts against tuberculosis.

Another reason why sanatoria have not been more successful is due to the large proportion of advanced cases admitted. Bigelow and Pope estimate that as late as 1933, over 80 per cent of the patients in tuberculosis sanatoria are in the moderately advanced or far advanced stages of tuberculosis on admission. While the active case of tuberculosis should be removed from the home where he is a menace to his household, the value of sanatorium treatment will not be realized fully until a larger number of early and favorable cases of tuberculosis are brought under treatment. They should comprise at least 25 per cent of the cases under treatment, and preferably more, especially if more emphasis is to be placed on the sanatorium treatment of childhood tuberculosis. Through private physicians and public clinics, therefore, a greater number of early and favorable cases of tuberculosis must be found and placed under effective sanatorium treatment.

In order to be effective, sanatorium treatment must also be long enough in duration. A minimum residence of six months should be required, and wherever possible, or where the need is indicated, residence should be longer. This is particularly true in the treatment of young people under twenty suffering from early tuberculosis. At the Massachusetts State Tuberculosis Sanatorium at Westfield, Mass., any child showing definite pulmonary involve-

ment according to X-ray pictures is given a minimum period of bed rest treatment regardless of symptoms. Drastic measures of this kind are necessary if tuberculosis is to be brought under control.

The most important factor in the treatment of tuberculosis is complete rest. Fresh air, sunshine, adequate nutrition, freedom from worry, etc., are necessary and desirable, but they are secondary in importance to rest. One of the most difficult things a tuberculous patient has to learn is how to take the rest cure. The transformation from a life of activity and freedom to one of complete inactivity in the horizontal position, not for a day or a week, but for months at a time, is an exceedingly difficult achievement. But the lesson must be learned if the fight which the individual wages against tuberculosis is to be won.

Certain surgical aids which have been brought to the assistance of the tuberculous in recent years, are included under the term "collapse therapy." They comprise primarily artificial pneumothorax, thoracoplasty, and phrenicotomy. According to Dr. Henry D. Chadwick, the originator of the Ten-Year Childhood Tuberculosis Program in Massachusetts, and recently Director of the Division of Tuberculosis in the Detroit Health Department, the use of pneumothorax and thoracic surgery is applicable to at least 75 per cent of the patients when pulmonary tuberculosis is first diagnosed. Dr. Frederick T. Lord, President of the Massachusetts Tuberculosis League, reports that lack of favorable progress among children under 20 who have definite pulmonary involvement and who are on bed rest treatment, indicates early resort to collapse therapy.

The purpose of collapse therapy is to provide complete rest for the affected lung by inactivating its use. In artificial pneumothorax, air or oxygen is introduced into the pleural cavity to collapse the affected lung. It is the most conservative of the surgical methods now employed, and is almost always used first. Thoracoplasty refers to the surgical removal of short segments of the ribs along the spine. This results in the collapse of the chest wall and the subsequent collapse of the lung on the side under treatment. In this way the affected lung is brought under complete rest, and the cure of the tuberculous process is facilitated. Phrenicotomy refers to the severing of the phrenic nerve in the neck which controls the diaphragm under the affected lung. Again, the lung is

collapsed, although the extent is not equal to that achieved by the two other methods. Dr. Chadwick says, "the beneficial results of collapse therapy have been so apparent that each patient on entering a sanatorium is considered for that form of treatment. It is felt that the only patients to whom collapse therapy of some kind is not applicable are those with very early lesions and slight involvement, those with bilateral disease so extensive that both lungs are completely involved, or those with advanced lesions and complications of a serious nature." Collapse therapy is used as a supplement to bed rest and not as a substitute. Since its introduction the results of sanatorium treatment have been materially improved. At the William H. Maybury Sanatorium in Detroit, where favorable cases of tuberculosis are under treatment and where collapse therapy has been practised since 1927, Dr. Chadwick reports that the percentage of patients discharged "apparently arrested" increased from 8.1 per cent in 1927 to 35.4 in 1932, and that the corresponding data for those discharged as "arrested, quiescent or improved" were 45.4 per cent and 69.8 per cent, respectively. During the same period the deaths were reduced from 25 per cent to 6.5 per cent.

The treatment of the disease alone is not the sole responsibility of the sanatorium toward each patient. His mental state must be taken into consideration and provision should be made to help him regain his earning capacity and self-respect in society. Toward this end, occupational therapy under expert supervision has been instituted at most sanatoria, and the patient is allowed to work as much as the supervising physician thinks his condition permits. In this way, patients learn to use their hands or their minds again; they experience the pleasure of earning once more; and their mental attitude is benefited enormously. But the responsibility of the sanatorium is not ended when the patient is discharged. An effort must be made to find him suitable and remunerative employment and to provide adequate follow-up work through the public health or tuberculosis nurse and the local tuberculosis clinic to prevent a relapse. Various schemes have been developed for reclaiming the tuberculous who are discharged as arrested cases. Special work colonies and shops have been established where all the employees are ex-tuberculous patients, where the work is adjusted to the requirements of each individual, and where each person works under expert medical supervision. In general,

however, the provision for discharged sanatorium cases still represents one of the most neglected fields in the entire anti-tuberculosis campaign.

The National Tuberculosis Association. — Any discussion of the tuberculosis problem in the United States would be incomplete without reference to the remarkable influence which the National Tuberculosis Association has had in stimulating anti-tuberculosis work. Prior to 1904 there were public spirited groups in some of our large cities, like Boston, Cambridge, New York, Philadelphia, and Baltimore, who, moved by the appalling toll of tuberculosis, united in efforts to ameliorate its evil effects. Since then their number has increased tremendously. The cause enlisted the leading men and women in every community, the outstanding physicians, philanthropists, educators, religious, business, and social leaders. They campaigned in the press, on the public platform, in the pulpit, in schools, in industry, and in the home. They influenced state legislatures, city councils, boards of aldermen, and political bosses. Always the campaign against tuberculosis was waged with the fervor — almost the fanaticism — of a religious crusade. The results speak for themselves. In a brief generation, a nation-wide effective organization has been built up, which functions every day in the year in the relentless campaign against a disease that was once and in many respects still is the arch enemy of mankind.

The National Tuberculosis Association was organized in June, 1904. It was known then as the National Association for the Study and Prevention of Tuberculosis. The shorter name was adopted in 1918. It was probably the outgrowth of the Laennec Society organized by Sir William Osler in 1900 at the Johns Hopkins Hospital in Baltimore. Laennec was a famous French physician who invented the stethoscope and who was very much interested in tuberculosis. The purpose of the Laennec Society was "to systematize and stimulate the work in tuberculosis in the hospital and to diffuse in the profession and public a knowledge of the disease." A public tuberculosis exposition was organized in Baltimore in 1904, and this proved such a successful and popular means of education that it was decided to make the campaign nation-wide. The organization of the National Association for the Study and Prevention of Tuberculosis followed, and Dr. Edward L. Trudeau was made President and Dr. William Osler,

Vice-President. Other distinguished men, laymen as well as physicians, followed in their wake and have carried on with the same crusading zeal. Since 1904 the National Tuberculosis Association has organized affiliated branches in every state in the Union and in almost every city, town, and hamlet, until its influence permeates even to the remotest rural or mountain fastness. Its chief support for its manifold activities is derived from the annual sale of Christmas seals. Its work has been largely educational and from the start its object has been to bring to everybody a knowledge of the facts regarding the nature, treatment, and prevention of tuberculosis. It has conducted studies and demonstrations, developed standards, educated the personnel necessary for its work, financed laboratory researches, engaged in statistical and field researches, initiated campaigns of popular and personal health education, stimulated the organization of clinics and sanatoria, and performed a great variety of other functions all of which have played their part in the national control of tuberculosis. Its record is a shining example of the great good a voluntary health organization can accomplish by stimulating intelligent action and enlisting the coöperation of the community.

There is an old Arabian proverb which says "he who has health has hope; and he who has hope has everything." The phenomenal decline in the mortality and morbidity from tuberculosis witnessed in the United States during the past fifty years has brought life and hope and happiness into the homes of countless families all over the land. The unity of families has been retained. Children have grown up under parental care and guidance. A great victory for human health and happiness has been achieved, and the future beckons to make the triumph complete.

CHAPTER XXVI

CHILD HEALTH — PUBLIC HEALTH ASPECTS

Historical. — When the history of the twentieth century is recorded, doubtless one of the outstanding achievements of the first thirty-three years will be the progress in the protection and saving of child life. The present situation is vastly different from that which prevailed 50 to 80 years ago, when the birth rate was 30 or more per thousand population, when half of all children born alive died before they reached their fifth birthday, when one-third of all deaths were among children under two, and when diphtheria exacted an annual toll in child life equal to or greater than the present total mortality from tuberculosis. The rise in popular and official interest in child life has truly been remarkable. While the child has always made a strong emotional appeal, official recognition of his potential value to the community and of the importance of providing for his welfare, have been fully appreciated in this country only in recent years. The importance of safeguarding the health of domestic animals and of combating the diseases of wheat, corn, cotton, and other crops, received governmental recognition long before the health of the child. This interest was stimulated by the economic needs of the people, but a civilized and progressive country should manifest an equivalent interest at least in its principal natural resource — its children.

The situation today has changed greatly from that which prevailed even at the beginning of the twentieth century. The Federal Government now supports child health and welfare activities through the Children's Bureau, the Public Health Service, the Bureau of Education, and various other agencies. Furthermore, every state in the Union and every reasonably large city have official child health programs. Again, among the most popular bulletins published by the U.S. Government today are those on Prenatal Care, Infant Care, and Child Management, while similar literature is provided by various state and city departments of health.

Private and philanthropic agencies have also participated in this progressive movement, often stimulating official activity and paving the way for essential community action. The organization of the American Association for the Study and Prevention of Infant Mortality, and of the Child Hygiene Association of America, and their subsequent combination into the American Child Health Association are indicative of the popular, philanthropic, and professional interest in child health. Mr. Herbert Hoover has been the active president of the American Child Health Association ever since its organization, and other men and women of national prominence have helped to guide its activities. The National Tuberculosis Association has also conducted child health work and child health education throughout the United States for years. The Commonwealth Fund financed the child health demonstrations of Fargo, N.D., Clarke County and Athens, Ga., Marion County, Oregon, and Rutherford County, Tennessee. The Cousens' Fund in Michigan is devoted exclusively to work among children. The Rockefeller Foundation, through its various divisions, has also participated in the child health movement. Diet kitchens and maternity centers have been established under private auspices; milk stations and infant welfare clinics have been organized; home visiting for educational purposes has been fostered; dental clinics have been established; and numerous other child health and welfare activities have been undertaken. In Boston the income from a large fund left to the city by the late George Robert White "to promote the public welfare," has been used largely for the construction of seven magnificent health units, in each of which child health work is the predominant activity.

The reasons for this almost universal interest in child health are, in part, the purely sentimental and emotional appeal which the child makes because of its weakness and dependence on the one hand, and its potential strength and greatness on the other. The World War, however, demonstrated the absolute economic need of conserving child life. Many of the civilized nations of the world were sacrificing their best young manhood; blockades and food shortages were affecting almost all the European powers engaged in the war; child life was suffering; and something had to be done to conserve it in order to perpetuate each national unity. Furthermore, the astonishing disclosures of the Boer War and

later, the World War, which showed that preventable, incapacitating physical defects among young adult males were altogether too prevalent, aroused governmental officials to action. In the United States over one-third of the young males between 21 and 31, drafted for military service during the World War, were found unfit because of one or more preventable physical defects due to neglect in childhood. At the time the United States entered the World War only five states had organized divisions of child hygiene, but within five years after the close of the war forty-three states had organized such divisions, and the movement spread rapidly throughout the land.

France was perhaps the first among the great nations of the world to initiate many of the child health and welfare activities now associated with a modern child welfare program. With a constantly decreasing birth rate and a death rate equal to and sometimes exceeding it, child life became unusually precious and the need for saving each newborn life became apparent if the very existence of France were not to be imperiled. In Germany, where the birth rate was very high and the death rate comparatively low, there was an annual substantial increment in the population. In time the population of Germany equalled and later surpassed that of France. Since national supremacy, in a military sense, is fundamentally dependent on man-power, the birth rates, death rates, and infant mortality rates assumed great national and even international significance.

France was the first country to organize institutions for foundlings, to establish the crêche, or day nursery, to enact laws for the protection of illegitimate children and to provide pensions for mothers. France also first organized infant milk stations, and school medical inspection had its beginnings in that country as early as the middle of the nineteenth century. Unfortunately these instruments for conserving infant and child life have not been maintained with the greatest effectiveness, for infant and child mortality in France is still needlessly high.

In the United States the first official bureau of child hygiene was organized in August, 1908, as part of the New York City Department of Health, and it was not until April, 1912, that the Federal Children's Bureau was organized. The establishment of the Children's Bureau was the direct outgrowth of the first White House Conference on Child Health, convened by President Theo-

dore Roosevelt in 1909, which concerned itself largely with the dependent child.

The function of the Children's Bureau is to investigate and report on all matters pertaining to the welfare of children and child life, including infant and maternal mortality, child management, the care of the adolescent, etc. Under the able leadership first of Miss Julia Lathrop and later (1922–1934) of Miss Grace Abbott, the Bureau has demonstrated in many ways its beneficent influence on child and maternal life in the United States.

The second White House Conference on Child Health was called by President Woodrow Wilson in 1919 and showed the influence of the war on matters affecting child and maternal life. This Conference dealt primarily with the economic and social basis for child welfare standards, with child labor, with the health of mothers and children, with children in need of special care and with the standardization of child welfare laws. One of the results of this Conference was the enactment in November, 1921, of the Sheppard-Towner Act to promote the welfare of maternity and infancy. As a result, Federal aid became available to those states willing to make a necessary basic appropriation to initiate prenatal, obstetrical, and infant welfare activities. Nearly all the states in the Union availed themselves of this aid and a national program to promote infant and maternal welfare resulted. The New England states, New Hampshire excepted, with typical and laudable independence, felt that they were conducting an adequate infant and maternal welfare program already and that Federal aid was therefore unnecessary.

The present national interest in child health work is however best illustrated by the third White House Conference on Child Health and Protection which was convened by President Herbert Hoover from November 19–22, 1930. It brought to Washington about 3,000 men and women, leaders in the medical, public health, educational, and social aspects of child welfare work. The Conference was preceded by sixteen months of careful preparatory study and research in which about 1,200 expert workers participated. As a result, a vast amount of reliable data on all phases of child health and welfare problems has been assembled and made available in permanent form in the White House Conference reports. Thus the basic material is now in convenient form for a modern infant, child, and maternal welfare program.

The magnitude of the child health problem. — According to the data assembled by the third White House Conference on Child Health and Protection there were in the United States in 1930 approximately 45,000,000 children. Of that number, 35,000,000 were reasonably normal. There were, however, 6,000,000 children who were improperly nourished; 1,000,000 who had speech defects; 1,000,000 who had weak or damaged hearts; 675,000 who presented behavior problems; 450,000 who were mentally retarded; 382,000 who were tuberculous; 3,000,000 who had impaired hearing; 18,000 who were totally deaf; 300,000 who were totally crippled; 50,000 who were partially blind; 14,000 who were wholly blind; 200,000 who were delinquent; and 500,000 children who were dependent. While these deficiencies are not always related to health, they indicate the present magnitude of the child welfare problem in the United States.

Data are available to show that there is still a great deal of unnecessary morbidity and mortality among infants and children. The White House Conference on Child Health and Protection estimated that there are at least 10,000,000 children in the United States with correctable defects, more than 80 per cent of whom are not receiving the necessary remedial or preventive attention. For example, about 95 per cent of the children in the United States suffer from dental caries. Over 3,000,000 cases of theoretically preventable communicable disease are reported annually. These cases are directly responsible for 15 per cent of all the deaths in the United States and their indirect toll is immeasurable. They bring about permanent disabilities like blindness; they damage the heart and kidneys; and they create a greater susceptibility to other infections which may handicap the child throughout life. The Conference also reported that 50 to 75 per cent of the crippled children in the United States owe their condition to poliomyelitis and tuberculosis, both of which are theoretically preventable diseases.

Smallpox and diphtheria are two diseases that can be definitely prevented through the use of specific biological products. The case of diphtheria prevention and control will be discussed later in this chapter but a word may be included here concerning the progress made against smallpox and the necessity of eliminating this disease entirely. In the early part of the nineteenth century, 20 per cent of all children died of smallpox before they reached age 10,

and one-third of all the deaths occurring among children from all causes were due to this disease. In 1928, in the U.S. Mortality Registration Area, which comprised about 95 per cent of the population, there were only 131 deaths from smallpox. Of this number, 30 per cent occurred among children under 5, of which more than two-thirds were among infants under one. While the present mortality from smallpox is gratifyingly low, it is important to realize that smallpox is still too prevalent in the United States and that the disease can be prevented entirely through successful vaccination. Dr. Samuel B. Woodward of Worcester, Mass., long a student of the subject, reports that in the decade from 1919 to 1928, there were over 553,000 cases of smallpox in the United States, or an average of 55,000 cases per year.

Infant mortality. — In order to understand the various phases of the child health problem it is necessary to analyze it into its component parts. Since infancy and early childhood are intimately associated with the welfare of the mother, prenatal care and preventing maternal mortality become integral parts of any well-ordered child health program. Included, too, is the problem of preventing stillbirths, and the necessity of improving the quality of obstetrical service in order to achieve this end. But child health work has revolved primarily around the infant, the preschool child, and the school child, and since excellent progress has been made in reducing infant mortality in the United States, this phase of the child health problem will receive prior consideration.

The infant mortality rate has been regarded as the best single index of the effectiveness of municipal or county public health work. It is also an excellent index of the enlightenment, the intelligence, and the civic consciousness of a community. It is defined as the number of infant deaths per 1,000 live births occurring in a community during one year. An infant is defined as a child under one year. At the beginning of the twentieth century infant mortality rates as high as 150 or more were not uncommon in the United States. In 1932 the infant death rate for the U.S. Birth Registration Area had been reduced to 58, and in some states, notably Oregon, Washington, Kansas, Nebraska, and Iowa, the rate was below 50. New Jersey joined this select group in 1933, the infant mortality rate being 46. In the same year the infant death rate in Pennsylvania, a highly industrialized state, was only 52, while in New York City, in spite of congestion and other draw-

backs, the rate in 1932 had already fallen to 51. The saving of infant life in the United States since 1900 has been phenomenal and today this country ranks among the leaders in the control of infant mortality. In 1931 the countries showing lower infant death rates than the United States were New Zealand, 32; Australia, 47; Switzerland, 49; Netherlands, 50; Sweden, 54; and Norway, 55. However, these countries have more homogeneous populations, and it is doubtful whether they have to contend to the same degree with the problems associated with large, foreign-born, uneducated groups, and the employment of numerous women in industry such as are found in the textile and canning pursuits.

Although the reduction of the infant death rate in the United States has been praiseworthy, it is important to realize that infant deaths still represent an appreciable proportion of the total deaths in any community. Thus, in Pennsylvania in 1933 the 8,299 infant deaths were responsible for approximately 8 per cent of the total deaths at all ages reported that year. In Detroit in 1932 the infant death rate was only 52 but the 1,356 infant deaths represented 8.3 per cent of the deaths at all ages. In Newark, N.J., in 1932, the infant mortality rate was only 42, but the infant deaths represented 7.6 per cent of the deaths at all ages. However, in 1912, twenty years earlier, the infant deaths in Newark represented 20 per cent of the deaths at all ages. Again, in 1932, there were 4,865 infant deaths reported in upstate New York, while during the same period only 4,022 deaths were reported in the same area for the age group 1 to 19. In other words, more deaths occurred during the first year of life than during the next nineteen years.

These data demonstrate that infant mortality still is a significant public health problem. Furthermore, the progress made in conserving infant life has been accomplished almost entirely beyond the first month of infancy. There has been a marked reduction in the deaths resulting from gastric and intestinal disorders and from the respiratory diseases, but little progress has been made in reducing the very early infant deaths resulting from prematurity, congenital debility, malformations, and injuries received at birth. In upper New York State, in 1932, 63 per cent of the 4,865 infant deaths occurred during the first month of life — the neonatal infant mortality — and of those who died during the first month of life, approximately 50 per cent lived only one day. In Massachusetts, in 1931, there were 3,803 infant deaths or an infant death rate of

54.8. Of these deaths, 30.1 per cent occurred during the first day of life; 51.1 per cent during the first week of life; and 61.1 per cent during the first month of life. Of all the infant deaths, 72.7 per cent occurred during the first three months of life, while 84.6 per cent occurred during the first six months of life.

If infant mortality is analyzed by cause as well as by age, certain interesting and important facts are disclosed. At one time gastric and intestinal disturbances were the leading cause of infant mortality. The rate would go up sharply during the warmer months of the year when the combination of temperature, unfit milk, and improper feeding would prove too much for many infants. This is illustrated in the case of Newark, N.J., whose experience is typical of the conditions that prevailed throughout the United States, often to an accentuated degree. In 1912, the death rate from diarrhea and enteritis among children under two years of age in Newark was 87 per 100,000 of the population. In 1932, the death rate was only 3.5, a reduction of 96 per cent. Intelligent feeding, safe milk, and the education of the mother in the requirements of infant hygiene have deprived the hot weather of most of its terrors, have eliminated the erstwhile summer peak in the curve of infant mortality, and have saved literally hundreds of thousands of infants from premature death.

It is now evident that the bulk of the mortality among infants occurs during the first month of life, in fact, during the first few days of life, and is associated with prenatal and obstetrical service. The data already given for Massachusetts in 1931 are but typical of the national conditions. Most of these deaths were due to prematurity, congenital debility, malformations, or injuries received at birth, for of the 2,082 infants who died from these causes before reaching the age of one year, 47.6 per cent died in less than one day, 77.2 per cent in less than one week, and 87.7 per cent in less than one month.

The second most important cause of infant deaths — gastric and intestinal diseases — claimed only 246 infants or 6.5 per cent of the total infant deaths, while the deaths due to pneumonia, broncho-pneumonia, and acute bronchitis combined, were 628 in number, or 16.5 per cent of the total infant deaths. The deaths due to the acute communicable diseases like measles, scarlet fever, whooping cough, diphtheria, influenza, and tuberculosis were 134 in number, or 3.5 per cent of the total infant deaths. Doubtless

some of the deaths charged to the pneumonias and acute bronchitis should have been assigned to one or more of the acute communicable diseases.

The control of infant mortality. — The marked progress in the United States in the control of infant mortality stimulates inquiry into the factors that have been operative. Some of these are undoubtedly identified with the control of the environment and its effect on health which this country has witnessed since the beginning of the twentieth century, and which earlier chapters describe; some are related to improvement in social and economic conditions; and some are associated with better medical, nursing, and midwife care during the prenatal period, at the time of delivery, and during the period of infancy.

Improvement in social and economic conditions has also had a beneficent influence on infant mortality. Improvement in wages and the resulting betterment in the general standard of living, the gradual curtailment and the expanding supervision of the employment of women in industry, the shorter work day and work week, the elimination of industrial hazards for women particularly, such as heavy lifting, straining, and unnecessary and undue fatigue, and the gradual infiltration of enlightenment into the home through the medium of the school, the public health nurse, the prenatal and infant welfare clinics, the newspaper and radio, and the wide variety of instruments now used for spreading health education are among the beneficent social and economic factors referred to above. While these are not always measurable with the same exactitude as time, space, temperature, and weight, they are significant nevertheless and the popular support accorded to them testify to their value. Infancy more than any other period in the life of the individual requires intelligent care and scientific knowledge to prevent illness and premature death. It was the late Dr. L. Emmet Holt — a distinguished pediatrist — who said, "it is not the unfit but the unfortunate baby that dies." It has also been remarked that "in the last analysis every mother must save her own baby," and to do so she must have the guidance resulting from scientific knowledge.

The requirements for healthy infancy are essentially the simple rules of hygienic living, but it has taken the race centuries to discover and apply them in the rearing of its young. The specialist in pediatrics today is the hygienic adviser of the mother, and wherever public infant welfare clinics are held they serve the same

purpose. The protection of the baby's food supply, the modification of milk to meet the requirements of each infant, and proper attention to cleanliness, sleep, clothing, ventilation, fresh air, sunshine, vitamin, and other nutritional requirements, suitable bowel functioning, correction of physical defects, and immunization against smallpox and diphtheria are some of the items that make for healthy, normal infancy.

The conquest of infant mortality has been largely accomplished. There remains, however, the glaring disproportion of infant deaths occurring during the first month of life, which is properly associated with prenatal and obstetrical care. Further progress against this form of infant mortality — the neonatal mortality— can be made only through adequate and satisfactory prenatal care and competent obstetrical service at the time of delivery. Since the welfare of the infant and other young children in the family depends on the welfare of the mother, the subject of maternal mortality must receive consideration in this chapter, especially as progress in this field of preventable mortality has not been commensurate with the reduction of infant deaths, particularly after the first month of life.

Maternal mortality. — Maternal mortality is defined as the deaths occurring among women which are associated with pregnancy or childbirth. In the United States there are approximately 16,000 maternal deaths annually. Among women of child bearing age, 15 to 44 years, the death rate from puerperal causes exceeds all others except tuberculosis. The maternal death rate in the United States is one of the highest in the civilized world and has remained stationary at a time when notable achievements in the saving of human life in other directions have been accomplished. For these reasons and because our high maternal death rate is amenable to control through proper prenatal hygiene and obstetrical service, the subject is receiving increasing attention.

In the U.S. Birth Registration Area for 1930, the maternal death rate was 6.7 per 1,000 live births. This rate was materially in excess of the maternal death rate in Denmark, England and Wales, New Zealand, Sweden, and Switzerland. Although puerperal septicemia is entirely preventable, 36 per cent of the maternal deaths in the United States in 1930 were due to this cause. The White House Conference on Child Health and Protection estimated that 40 per cent of the maternal deaths are due to infections, approximately 25 per cent to toxemias, and 8 to 10 per cent to

hemorrhages which are at least controllable if not entirely preventable. Thus at least 75 per cent of the maternal deaths occurring in the United States are theoretically preventable. The report of the Conference states that "if our present day obstetrical knowledge could be universally and skillfully applied, several thousands of maternal lives, and tens of thousands of fetal and infant lives could be saved annually, and much suffering and injury avoided. It is unlikely that the maternal and early infant mortality in this country will be above reproach until certain minimum and fairly uniform requirements are met before a license is granted for the practice of obstetrics." The Conference concluded that adequate care for maternity cases in the home and hospital, the latter with a segregated maternity service, should be available in every urban and rural community, and that adequate medical education is fundamental to any program for maternal care.

Although New York City is a great medical center and it might therefore be expected that prenatal and obstetrical service would be developed there to a high degree of general expertness, the maternal death rate is similar to that for the country as a whole. The maternal death rate in 1930 was 5.43 per 1,000 live births, and although the death rate from puerperal septicemia had been diminished from 2.0 to 0.92 per 1,000 live births from 1898 to 1930, the total maternal death rate remained practically stationary during this period. The New York Academy of Medicine studied the 2,041 maternal deaths which occurred in New York City during 1930, 1931, and 1932, and concluded that 1,343, or 65.8 per cent, of these deaths could have been avoided if the patient had had suitable medical care, and that 60 per cent of these preventable maternal deaths were the result of some incapacity in the attendant obstetrician, such as lack of judgment, lack of skill, or plain carelessness. As a result of this and similar disclosures in other parts of the United States, the leaders of the medical profession are keenly aware of the existing situation and are taking steps to improve the training of medical students in obstetrics, and to supervise in some way the obstetrical practice in each community.

That adequate prenatal care and proper obstetrical service at the time of delivery can effect a saving in maternal mortality has been demonstrated on various occasions. The Maternity Centre Association of New York City conducted such a demonstration

over a period of eight years. Almost 5,000 mothers were included in this study. The maternal death rate among those women receiving adequate prenatal care and proper obstetrical service at the time of delivery was only 2.2 per 1,000 live births, while the death rate among similar mothers living in the same district, often next door, who did not have the benefits of the first group, was 6.2 per 1,000 live births. In other words, a saving of 66 per cent in maternal mortality was effected by scientific care and supervision. Similar results were obtained in Birmingham, Alabama, in 1931. Among the 1,500 expectant mothers who attended the Jefferson County Health Department prenatal clinic, the maternal death rate was 3.6 per 1,000 live births, whereas the rate for Jefferson County as a whole was 9.5 per 1,000 live births.

That adequate maternity care is becoming a matter of community concern and public health interest is apparent from the following statement taken from a plan for public maternity care proposed by Dr. Thomas Parran, Jr., State Commissioner of Health for New York and reported in the *N.Y. State Health News* for May 21, 1934. After noting that there were 1,168 maternal deaths in New York State in 1933, coupled with 8,000 stillbirths, 3,000 infant deaths during the first day of life and another 3,000 infant deaths during the first month of life, Dr. Parran says — "Safer childbearing, fewer disabled women, fewer dependent children, fewer stillborn babies are objectives of as great community concern as the control of tuberculosis. I believe these objectives can be attained in great measure by (1) better quality of professional care through an aroused public and professional opinion; (2) a reduction in criminal abortions; [Dr. Parran maintains that abortions are responsible for 25 per cent of all the maternal deaths]; (3) a larger effort by health departments in providing prenatal supervision; and (4) the provision of public maternity care on the basis of medical need rather than pauperism."

While it is not the province of this text to describe the requirements of adequate prenatal care and satisfactory obstetrical service at the time of delivery, since these items belong essentially to the field of medicine, certain aspects of the subject which have public health significance may be noted here. It is essential that every expectant mother should have adequate prenatal care, under her own physician if possible, and if not, at public prenatal clinics. The first public prenatal service in the United States was organized

in Boston in 1912 by Mrs. William Lowell Putnam, and conducted under the auspices of the Woman's Municipal League. The famous Maternity Centre Association of New York City, which has done such effective work, was organized in 1918. Since then, prenatal care at public expense has been provided in a great many communities at health centers and special clinics. The medical profession has not always supported such clinics on the ground that they interfered with private practice, but the clinics or conferences have persisted, and because they fill a great public need, they have grown steadily in number.

The work of the prenatal clinic is essentially hygienic and its aim is to prevent accidents or injury to the mother and the expected child. Prenatal supervision should begin early during pregnancy, during the second or third month if possible. Pelvic measurements to eliminate mechanical difficulties at parturition are made, the urine is examined, and the blood pressure observed with increasing frequency as the pregnancy develops, the heart is also examined, the weight is carefully observed, and the expectant mother is instructed concerning diet, water consumption, proper elimination, care of teeth, cleanliness, sleep, rest, fresh air, sunshine, exercise, work, and other requirements for hygienic living. The blood is examined for syphilis and vaginal smears may be examined for gonorrhea. If either disease is present, suitable treatment is instituted. The expectant mother is informed of the danger signals of pregnancy and she is instructed in the requirements for delivery and in the early care of the infant.

Among the foreign-born population of our large cities and among the negroes in the south midwives often attend the mother during childbirth. In such cases there is little or no prenatal care. Often the midwife is untrained and ignorant of the essentials of asepsis, antisepsis, and ordinary cleanliness. In Massachusetts the midwife is legally prohibited from practising her art, although she does so to some degree still and reports the births she attends to the proper registration officials. Many attempts have been made to provide suitable training for midwives as it is impossible to eliminate them at present. A school for midwives is operated in New York under excellent auspices, and the American Child Health Association has conducted courses in the south for the training of colored midwives.

Strangely enough the maternal death rate among mothers de-

livered by midwives often compares favorably and sometimes excels the rates among mothers attended by physicians. This is because difficult deliveries are frequently turned over to physicians when danger signs appear; but even if such cases are excluded the midwife often makes a creditable showing in comparison with the general practitioner. The answer for this paradox is found in the fact that the midwife lets "nature take its course" whereas the physician is often impatient and interferes with the delivery process. With the increasing use of physicians as obstetricians, with a steadily increasing proportion of births occuring in hospitals rather than the home, the conditions are theoretically favorable for a reduction in maternal deaths. Since this has not been accomplished it is evident that obstetrical practice must be supervised by the more expert practitioners and that the coming generation of physicians must receive more adequate and effective training in obstetrics before being allowed to practice.

Stillbirths. — Associated with the problem of maternal health and welfare is the question of stillbirths which in the United States represents an item of major importance. For every 100 babies born alive in the United States about four are stillborn. This is true even in the best medical centers where expert obstetrical aid is available. Furthermore, the stillbirth rate has remained practically stationary as the data below for Massachusetts indicate. In 1931 there were 2,440 stillbirths recorded in Massachusetts.

TABLE 41

STILLBIRTHS PER 100 LIVE BIRTHS IN MASSACHUSETTS, 1926–1931

YEAR	STILLBIRTHS PER 100 LIVE BIRTHS
1926	3.59
1927	3.61
1928	3.57
1929	3.43
1930	3.52
1931	3 52

In Detroit, Michigan, which is also a great medical center and which has one of the best health departments in the United States, the stillbirth rate in 1932 was 3.4 per 100 live births. In Pennsylvania in 1933, the rate was 3.89.

Doubtless some stillbirths are unavoidable, but it is likewise true that many can be prevented. for stillbirths are often due to

lack of proper prenatal care and competent obstetrical service at the time of delivery. The prevention of this unnecessary sacrifice of human life is, therefore, a matter of legitimate interest to the progressive health officer and the medical profession. Since syphilis in the mother is frequently responsible for stillbirths, the existence of the disease in the expectant mother should be determined early during pregnancy and proper medical treatment provided. Other factors associated with stillbirths, many of which are controllable, are malnutrition and general debility of the expectant mother, excess fatigue due to overwork, severe illness, falls, injuries and other serious accidents, fright, shock, and induced labor.

Preschool child health. - Nearly all of the infant welfare clinics or conferences in the United States provide supervision not only for infants but for children under two. Between the ages of two and six, very little has as yet been done by public health officials to provide the supervision and guidance which this group requires. The preschool age period has been described as the most neglected in the public health program. This is due largely to the difficulty of assembling these young children in clinics. This age group, however, is so responsive to preventive medical and hygienic treatment, and their hold on life is still so slight, that an organized effort to provide for their welfare should be made by public health authorities.

What are the essentials for the health protection of the preschool child? While it is impossible to protect him against all of the communicable diseases of childhood, it is possible to immunize him against smallpox and diphtheria. Statistics for Michigan show that the fatality rate for diphtheria — the number of deaths per 100 cases — is inversely proportional to the age of attack. During the first year of life, for example, it is 61 per cent; during the second year, 34.7 per cent; and during the third year, 21.4 per cent. Furthermore, most of the deaths from diphtheria occur during the preschool period. During 1927, 57 per cent of all the diphtheria deaths in Michigan occurred among children under five, while in Massachusetts in 1931, 53 per cent of all the diphtheria deaths occurred in this age group. The same situation prevails for measles, scarlet fever, and whooping cough. In the case of whooping cough almost 98 per cent of the deaths occurred in children under 5 in Massachusetts in 1931; in measles, 86 per cent; and in scarlet fever, 45 per cent. It is obvious, therefore, that

the prevention of the communicable diseases of childhood should be accomplished during the preschool period. Where biological products are not available, exposure to infection during these early years should be avoided. Later when the resistance of the child is improved, he may be better able to cope with disease. Immunization of children against smallpox and diphtheria should be accomplished during infancy. This procedure should be a regular practice at all infant welfare and preschool clinics. Physicians in private practice should acquaint each mother of the necessity of protecting children against these diseases and should urge their immunization. In children under three the use of convalescent or immune measles serum for contact cases is also recommended in order to eliminate needless mortality and to moderate the course of the disease.

Proper nutrition is also exceedingly important in the health of the preschool child. It must be adequate in amount and properly balanced with minerals and vitamins to insure good growth, satisfactory bone formation, and sound dentition. In the northern areas of the United States the use of some anti-rachitic substance such as cod liver oil, viosterol, haliver oil, or vitamin D milk is essential during the fall, winter, and early spring. The use of whole milk, and fruits and vegetables in liberal amounts, is also important. Without satisfactory nutrition, sound dentition and good growth are difficult, the resistance of the child is undermined, and he becomes susceptible to disease and serious defects. Some care must be exercised however to avoid excessive amounts of vitaminic preparations, since large doses may produce unfavorable results.

The preschool child should be examined periodically by a competent physician to discover early physical defects and to determine whether or not satisfactory growth is taking place. The detection of physical defects and their prompt correction before much damage has been done should curtail the need for extensive medical supervision during school life, and should have a favorable effect on the degenerative diseases which normally appear in adult life. Carious teeth, enlarged and diseased tonsils and adenoids, defects in hearing and vision, detective hearts or kidneys should receive corrective attention early in life if the best interests of the individual are to be served.

The other requirements for healthy childhood are essentially

matters of hygiene, and an effort should be made through the various channels now available, to inculcate and establish suitable hygienic habits which will be continuously maintained. Among these are cleanliness, especially of the hands and mouth, proper elimination, adequate water intake, proper rest, sleep, exercise, the use of fresh air and sunshine, avoidance of undue fatigue and excessive excitement, the proper management of tantrums, and learning how to live and play happily with other children. Such desirable physical and mental hygienic practices should insure normal and satisfactory development during childhood.

The anti-diphtheria campaign. — The conquest of diphtheria is one of the great triumphs of medicine and public health. Effective control against diphtheria began about forty yea s ago (1894), for it was then that diphtheria antitoxin was introduced in the treatment of the disease. Wherever widely used there was an immediate drop in the death rate from diphtheria. In New York City between 1894 and 1898 it was cut from approximately 175 per 100,000 population to about 50, due largely to the use of diphtheria antitoxin. However, the death rate continued high and it was only by the successive development of other aids to effective control, such as the pasteurization of milk supplies, the laboratory diagnosis of diphtheria, the use of toxin-antitoxin and subsequently of toxoid for active immunization, and the development of the Schick test to determine susceptibility to diphtheria, that the results of the present era have been attained. In 1876 the death rate from diphtheria in New York City was 300 per 100,000 population; in 1933 it was only 1.2. In 1933 there were eleven among the 93 large cities (over 100,000) in the United States that did not have a single death from diphtheria. These were Duluth, Elizabeth, Hartford, Rochester, Salt Lake City, Seattle, South Bend, Spokane, Springfield, Mass., Syracuse, and Yonkers. If non-resident deaths were excluded, Cambridge and Providence would be included in this list. The ten cities showing the highest diphtheria death rates in 1933 among the large cities of the country, had rates varying from 8.0 to 12.0 per 100,000 population, and included Atlanta, Dallas, Lowell, Louisville, Fort Worth, El Paso, Paterson, Houston, Chattanooga, and Knoxville. Even in the most congested centers — the largest cities in the United States — the death rate from diphtheria in 1933 was

exceedingly low. In Chicago it was 0.2 per 100,000 population; Philadelphia, 0.7; Detroit, 3.0; Boston, 3.3; St. Louis, 3.7; Cleveland, 2.6. Not only have death rates been falling, but the cases reported have diminished perceptibly in spite of an expanding population. In 1900 for example, Philadelphia reported 5,088 cases of diphtheria, while in 1929 only 969 cases were reported.

The *Statistical Bulletin* of the Metropolitan Life Insurance Company for January, 1931, appraising public health conditions in the United States for 1930, summarizes the remarkable public health victory against diphtheria in a particularly interesting way. According to this analysis "the diphtheria death rate in the brief space of three years was practically cut in half! In a single year it was reduced more than one-third! And since 1911 the rate has fallen four-fifths! The per cent decline in the diphtheria death rate outranks even that for tuberculosis. As an example of what it is possible to accomplish in the control of a communicable disease, diphtheria takes precedence over every condition save typhoid fever alone. The death rate has now declined to a point where the disease may no longer be ranked as a scourge of childhood! As the ever-increasing use of a toxin-antitoxin continues to render more and more children immune to diphtheria, and as early antitoxin treatment saves more children who have contracted the disease, we may confidently expect that in a relatively few years diphtheria will be a negligible factor in our mortality. Deaths from diphtheria today are due almost entirely to ignorance or carelessness on the part of parents."

The significance of diphtheria as a cause of death cannot be fully appreciated from the consideration of the total number of deaths alone. Earlier in this chapter reference was made to the large proportion of diphtheria deaths that occur in the age group under 5. It is not generally appreciated that until recently diphtheria ranked very high as a cause of death during the first few years of life. In New York City, for example, during the six-year period from 1923 to 1928, diphtheria mortality at age one ranked fourth in importance; at age two and three, it ranked second; at age four, it ranked third; and in the age group 5 to 9, it ranked second for females and third for males. In Pennsylvania during 1933 one-third of all the cases of diphtheria reported occurred in the age group 5 to 9, while one-fourth of the cases occurred among children under 5. Diphtheria, from the stand-

point of incidence and mortality, is distinctly a children's disease, and it is among this group that preventive and control measures must be applied. The period most conducive to the control of diphtheria is before age five as the following observation indicates.

Dr. E. S. Godfrey of the New York State Department of Health, in a special study conducted for the Committee on Administrative Practice of the American Public Health Association, has shown that the beneficial effects of a community program of diphtheria immunization depend chiefly on the success with which the children of the preschool age group are reached. He finds that even when 50 per cent of the child population between the ages of 5 and 14 has been immunized, the prevalence of diphtheria in the community may remain substantially unaffected. If, however, in addition to the protection of one-half of the school population, one-third of the children under 5 are also immunized, there is an immediate and sharp decline in the diphtheria death rate.

In New York State, where the campaign against diphtheria has been carried on with particular zeal, 15 per cent of the entire population had already been immunized in 1930. Those immune included 25 per cent of the population under 5, and 60 per cent of the population between 9 and 14. New York City, the home of Dr. William H. Park, the father of diphtheria prevention and control in the United States, immunized 211,985 children against diphtheria in 1929, and 169,466 more in 1930. Of the 381,451 children immunized during these two years, 33.5 per cent were under two years, 43.0 per cent were between two and six years, and only 23.5 per cent were over six years. The same praiseworthy accomplishment was achieved in Philadelphia. In 1930, the local health department estimated that those immunized against diphtheria included 40 per cent of all children under 5, 80 to 85 per cent of all children in the age group 5 to 9, and 60 to 65 per cent of all children in the age group 10 to 14. Such figures explain why diphtheria is no longer a menace to childhood. They also stand as irrefutable arguments against those who perennially oppose compulsory vaccination, diphtheria immunization, animal experimentation, and other life-giving procedures developed by science.

Immunization against diphtheria may be accomplished by the use of toxin-antitoxin or toxoid, the latter biological product having been developed more recently. Toxin-antitoxin is a mix-

ture of diphtheria toxin and antitoxin. The toxin is the poison elaborated by the diphtheria bacillus, and the antitoxin is its antidote which is produced in the horse. The mixture is titrated in such a way that its administration subcutaneously in three doses at intervals of one week, produces in the majority of susceptible children an active immunity to diphtheria. Toxoid, on the other hand, is free of antitoxin or the horse serum that contains it, and is prepared from diphtheria toxin which has been detoxified with formaldehyde. It is also administered subcutaneously, but only two doses with an interval of one month are required. An alum precipitated toxoid has been prepared recently (1933) which immunizes in a single dose.

Toxoid has certain advantages over toxin-antitoxin. First, it does not contain any horse serum and therefore does not sensitize the individual to this animal protein. This is desirable in case scarlet fever antitoxin or tetanus antitoxin has to be administered later to the same child. Second, only two inoculations are necessary instead of three. This is desirable for the child and the community, as it insures a higher proportion of completed immunizations. Third, immunity against diphtheria develops more rapidly with toxoid than with toxin-antitoxin. Fourth, the proportion of children rendered immune with toxoid is greater than with toxin-antitoxin. Fifth, toxoid is more stable than toxin-antitoxin and is less likely to deteriorate on storage; and finally, toxoid costs less to manufacture than toxin-antitoxin.

The health of the school child. — In the United States, there are approximately 38,000,000 children of school age, *i.e.*, between 5 and 20 years. In 1920, 64.3 per cent of the children in this age group were actually attending school. Assuming that the same rate of school attendance now prevails there are approximately 24,000,000 children of school age who are attending either elementary school, high school, college, or professional school. The large number of children in this group, as well as the considerable portion of their time devoted to school activities, makes the matter of health protection for them an item of public concern. It is now recognized that the early school years constitute the logical period for training and habit formation in hygienic living, and for the correction of physical defects which otherwise may later undermine the health of the individual.

The American school system may justly be regarded with pride.

One cannot travel through the country without being impressed with the magnificence of the buildings erected for elementary, intermediate, and higher education. In many rural districts the little one-room schoolhouse has been replaced by a small but modern school or by a large consolidated school which provides in either case a physical environment for the country child equal in comfort and attractiveness to that of the city child. Along with this development, the curriculum has expanded and become more progressive, and a system of health supervision and health education has been introduced. These changes are even more important than improvement in the physical environment but doubtless both will be further developed.

In the section dealing with the health of the preschool child, mention was made of the desirability of having each child admitted to school free of physical defects and immune to smallpox and diphtheria. An energetic public health campaign would be required to attain this end, and if successful, the necessity for school health work would be greatly curtailed. Under existing conditions, however, the school health program must still be regarded as essential to the modern public health campaign.

The school health program naturally divides itself into five main divisions, medical supervision, dental service, nursing follow-up work, teaching health practices, and school sanitation. Physical education is frequently and quite properly associated with the school health program, but it will not receive detailed consideration here.

The question often arises whether the health department or the school department should administer the school health program. Those in favor of vesting the responsibility in the health department maintain that since it is responsible for the health of the entire community, it would be unwise to transfer the supervision of the health of the school child population to another agency whose principal function is education. Furthermore, it is argued that the control of communicable disease, the correction of physical defects, the sanitation of houses and public buildings, and even health education in its broadest sense, are legitimately functions of the health department. On the other hand, school health education is an acknowledged part of the educational curriculum and is intimately interwoven with it, and physical education has always been regarded a part of the general education plan. Furthermore,

since school medical inspection, dental supervision, and nursing follow-up work deal with the school child and the personnel required must enter the schools and fit into the educational plan, it has been argued that from an administrative standpoint greater efficiency and less friction would be fostered if the school health program were under the school superintendent. Then the responsibility for the health of the school child would not be divided. It may be maintained that the health department and the school department should cooperate in administering the school health program, each limiting its responsibility to its proper sphere of activity, and while this plan is in operation in some communities, it usually does not function advantageously, and actually one or the other agency must accept complete responsibility. Among the cities in the United States having a population of 10,000 or more in 1930, 75 per cent had their school health work under the educational department, 15 per cent under the health department, and in the remaining 10 per cent there was joint responsibility. Although capable public health administrators would naturally favor health department control over the school health program, it must be admitted that under present conditions, the school health program functions more efficiently under educational supervision. In the case of the parochial schools, the school health program is always under the health department.

School medical inspection. — Medical inspection of school children was first introduced in the United States in Boston in 1894, in an endeavor to control an epidemic of diphtheria prevalent at that time. Since then it has become a part of the school health program in almost every community. In Massachusetts the annual medical inspection of school children is required by law. As is often the case, however, desirable legislation fails to yield the expected beneficent results. This is certainly true of the school medical inspection in most instances. Children are examined frequently at the rate of 60 to 120 or more per hour, and often without removing the clothing to the waist; the stethoscope may not be employed in examining the heart and lungs, and the educational value of the examination is rarely shared by the parents. Even where obvious defects are discovered, they frequently remain uncorrected only to be rediscovered and recorded at the next examination. Obviously, such effort is wasteful and it raises the question whether school medical inspection as conducted at present

in so many instances is worthwhile. Potentially, the medical inspection of school children, if conducted properly and with successful follow-up, should prove of great value.

One reason often given to explain the unsatisfactory status of school medical inspection is that the funds available for this work preclude the possibility of a more complete examination. This is unquestionably true, and the question naturally follows whether a thorough annual examination of each school child at public expense is really necessary, and whether fewer examinations conducted satisfactorily at suitable intervals during the school career of each child would not yield even better results. It has been suggested that each child be examined during the first, sixth, ninth, and twelfth grades. This would provide an examination on admission, one at the completion of the grade school period, which coincides ordinarily with puberty, another at the completion of junior high school, and the last at the conclusion of high school and before the child leaves for work or college. Such a plan should prove effective in providing satisfactory health supervision for each school child. The emphasis would then be transferred to the quality of medical service rendered and not merely on the number of examinations performed.

A thorough medical examination should include not only the health history of the child and the measurement of the height and weight, but likewise the examination of the eyes, ears, mouth, nose and throat, glands, skin, nutritional status, heart and lungs. Tests for defective vision and hearing, and the height and weight measurements may be made by the school nurse or teacher. This would relieve the examining physician. The school nurse could also be trained to take the medical history satisfactorily. If a school dentist is employed, he could make the dental examinations. The other examinations should be performed by the physician. Examinations should be made in a room reserved for the purpose, and the clothing should be removed at least to the waist. Boys and girls should be examined separately, and it may be wise in some instances to provide a woman physician to examine girls who have attained puberty. The heart and lungs should be examined with a stethoscope and while the time required for a complete medical examination will naturally depend on the items included, in general, about twenty minutes should be allowed for each child. An effort should also be made to have parents present

at the examinations, and to interpret the findings immediately without arousing unnecessary fears concerning the child's health.

One of the direct results of the discoveries in the field of nutrition has been the attempt to translate the findings on vitamins, minerals, and the other important elements in a complete and adequate diet into the daily lives of school children. Nutrition clinics and classes were organized for purposes of health instruction and dietary improvement; campaigns to place a set of scales in every school were waged; and a health program for many children was built up around nutrition as a base. It soon became firmly established in the minds of lay and professional people that the height-weight-age index was an excellent yardstick for measuring nutritional status and incidentally health. Doubtless much good was accomplished by the universal periodic weighing and measuring of children, for the process was linked up with health education and with instruction in the fundamentals of an adequate and satisfactory diet. The American Child Health Association has demonstrated, however, after an exhaustive and painstaking study, that there is no correlation between height and weight and the nutritional status of the child. On the other hand, it was found that measurements of the arm, chest, and hip girth — the ACH plan — do correlate with nutritional status. An effort is being made at present (1934) to introduce this newer method of measuring the nutritional status of school children.

Since medical inspection of school children is universally practised in the United States it is of interest to inquire into the nature and prevalence of the more common defects revealed by these examinations. The U.S. Public Health Service conducted a thorough investigation of illness, physical defects, and mortality among 30,000 school children between the ages of 6 and 18 in Maryland, Missouri, and Florida and published the findings in 1931 in *Public Health Bulletin No. 200*. The outstanding physical defects disclosed by these examinations are tabulated on page 525.

The school medical examination is but an occasional and hasty health inventory and even the supervision of the school nurse may be only intermittent. In between these medical and nursing surveys, the child may develop symptoms of communicable disease which may necessitate immediate medical attention. The prompt detection of such symptoms and the segregation of the affected child are essential in order to protect the other children in the

TABLE 42

SOME PHYSICAL DEFECTS DISCLOSED BY THE U.S. PUBLIC HEALTH SERVICE EXAMINATION OF 30,000 SCHOOL CHILDREN

DEFECT	PER CENT HAVING DEFECT
Prevalence of one or more decayed teeth	65.9
Prevalence of one or more filled teeth	28.1
Defective vision	32.5
Enlarged or diseased tonsils	30.7
Enlarged anterior cervical glands	25.4
Enlarged thyroid gland (simple goiter)	10.4
Enlarged submaxillary glands	7.2
Conjunctivitis, chronic or follicular	7.0
Enlarged posterior cervical glands	4.6
Cardiac defects	3.5
Defective hearing, one or both ears	3.1
Pediculosis	0.75
Ringworm	0.73
Impetigo	0 61
Scabies	0.19
Tuberculosis, definite or suspected	0 29

class. Two means are available for accomplishing this end. The first and most desirable is to detect such symptoms in the home. Every child should receive parental scrutiny every morning to determine its physical fitness for school. In this way early symptoms of disease would be detected, segregation would be prompt, and medical attention would be provided early. The second method is to have this daily health inspection performed by the teacher. She is with the child during a considerable portion of each day and she should be mindful of the appearance of early symptoms of disease such as running eyes or nose, a persistent cough, sore throat, enlarged glands in the neck, the appearance of a rash or other skin eruption, or the possible existence of chills or fever. There should be a daily teacher-inspection at the beginning of the morning session in order to eliminate the potential sources of danger as promptly as possible. The final decision to exclude a child from school because of illness should be made by the school physician or the school nurse, or in their absence, by the principal.

School dental service. — The proper care of the mouth, including the teeth, is exceedingly important. Proper digestion is fundamentally dependent on sound teeth, and the absence of defective teeth and their accompanying focal infections and sequelae is essential for good health and longevity. Since defective teeth con-

stitute the most common physical defect found in school children some form of dental supervision is an essential part of the general school health program.

The system of dental supervision may include dentists employed on a part-time basis, dental hygienists or dental assistants, dental examinations apart from the medical inspections, and dental clinics for filling and treating teeth as well as prophylactic treatments. Unfortunately the emphasis theretofore has been placed on the detection and correction of dental defects and not on prevention. Accordingly dental defects have flourished almost unabated in spite of extensive dental service in the schools. The statement that "a clean tooth never decays" is untrue, for in spite of dental cleanings and the use of the toothbrush, children's teeth have continued to show dental caries. While the aesthetic value of cleaning the teeth is unquestioned, it is now recognized that the really significant factor in the prevention of dental caries is nutrition. The diet of the child must be adequate in vitamins and minerals in order to build sound teeth and bones and to prevent dental caries. Therefore, the dental health program in the schools should be educational as well as reparative, and the emphasis should be placed on the important relationship between nutrition and sound teeth. If this program is started during the preschool period and is carried out successfully, the need for an elaborate dental health program in the schools will be greatly curtailed.

School nursing service. — The school nurse is the connecting link between the health program in the schools on the one hand and the home and social welfare and health agencies in the community on the other. If her work is effective, the school health program becomes a vital factor in health protection and promotion. On the other hand, if she spends her time taking children to public clinics, a responsibility that should rest with the parents, and neglects the educational aspects of her work, her contribution to the community program of health conservation and health promotion is exceedingly small.

The duties of the school nurse should be explicitly defined and there should be proper supervision to insure the performance of effective work. She should assist at all school medical examinations by preparing the children for the health inventory and by enlisting the coöperation of parents, principal, and teachers. She should prepare a complete medical, social, and school history of

each child on suitable forms so that they may be of aid to the physician in formulating his recommendations. She should weigh and measure each child at periodic intervals and conduct the tests for defective vision and hearing where the teacher does not perform these functions. She should make follow-up visits in the home to insure proper corrective medical or dental care for each child who needs it. She should acquaint each teacher with the health status of her children so that each child may receive the fullest benefit of the educational curriculum. She should give talks on health problems before parent-teacher groups and she should be on the lookout for symptoms of communicable disease during her visits to the classroom. Where health education is not a part of the regular school curriculum, she should organize such a program and make it part of her work. In some cases courses in hygiene, home nursing, child care, and first aid may also be organized. Where the school physician or other qualified person does not make periodic sanitary surveys of the school plant, the school nurse should learn how to make such inspections and should conduct them at least once or twice each year. Recommendations for necessary changes should be followed up tactfully until corrective action is obtained. The nurse must usually assume responsibility for readmitting children to school following communicable disease; she must render first aid in the absence of the school physician; and she is frequently required to perform the examination of the scalp and skin.

Health education. — The school environment is a peculiarly appropriate place for inculcating knowledge and habits of healthy living. Psychologically the child is most amenable to instruction and habit formation. Because of its value, health education has in many places become a fundamental part of the school curriculum, and is interwoven with the various subjects of instruction in an ingenious and interesting manner. It is correlated with art, language study, arithmetic, history, geography, science, and various other subjects. Plays and exhibits having health as the motif are organized, health books are constructed, compositions on health subjects, and health heroes are prepared, and a variety of other projects are undertaken and carried out successfully. It is impossible to visit any school where health education is a vital factor in the daily work without realizing the fundamental value of such instruction in the daily lives of the children. They often carry important health lessons into the home, and where this

occurs, significant changes in the dietary, in personal and environmental cleanliness, in the ventilation of the home, in the hours of sleep, and other essential hygienic practices are frequently introduced. The health education program also includes instruction in the necessary precautions against automobile accidents and other possible injuries, in the essentials of community and domestic sanitation, in the organization and functioning of the human mechanism, in the control of communicable disease, in the protection of water, milk, and other foods, in the proper disposal of liquid and solid wastes, and in the community forces available or required for effective public health protection.

For the most effective operation of a health education program it is necessary to have a properly qualified person — usually a health education supervisor. Without such direction and guidance, the nature and scope of health education in each classroom will depend on the interest and initiative of the individual teacher, and such a system is not likely to be very successful. The health education program must be carefully planned, the projects developed in detail, the coördination with other studies skillfully worked out, and the scope and nature of the work fitted to the intellectual and psychological level of each grade. Furthermore, it is necessary to have some stimulating personality constantly at work to maintain the interest of the teachers at the proper level of enthusiasm, to provide new and interesting ideas for the conduct of the work, and to give necessary scientific instruction to the teachers whenever necessary. The extent to which health education has been incorporated in the general educational curriculum bears witness to the fact that it is destined to be a permanent and expanding feature. The accomplishments of biological science in the control of disease and the promotion of personal health must be translated into the daily lives of the people, and health education in the schools is one of the avenues through which this desirable goal is being achieved.

School sanitation. — The school environment of the child constitutes an important factor in his health and development. If it is pleasant, attractive, healthful, and safe, he unconsciously forms lasting impressions of what a proper environment should be. If it is unclean, unattractive, and subject to nuisances arising from foul odors, smoke, and noise, he loses the value of the object lesson which a desirable school environment provides, and his

interest in attending school must be adversely affected. Happily, most schools in the United States provide a favorable and attractive environment, but specific sanitary deficiencies may be found in almost every instance.

The *school building* should be centrally located for the district it serves, readily accessible, within easy walking distance, and removed from dangerous street and railroad crossings. It should be located on high land and at a reasonable distance from potential or actual nuisances such as dumps, swamps, stables, factories, and sources of noise, foul odors, and dusts. In order to insure adequate natural lighting and ventilation the school must not be hemmed in by tall, surrounding buildings. The soil on which it is located should be permeable and dry and should contain little decaying organic matter. Adequate playground space — 100 square feet per child — should be provided. Suitable playground equipment should also be available. High schools require more extensive playground space to provide for running games, athletic fields, etc. About 10 to 12 acres of playground area are suggested as a minimum standard for high schools by the White House Conference on Child Health and Protection.

School buildings should preferably be constructed of fire-proof materials and except in congested areas should not be more than two stories high above the ground floor. Multiple entrances or exits located at two or more different ends of the building should be provided. The entrances or exits must be free of obstructions at all times, and the doors must open outward and be unlocked at all times while the building is in use. The provision of doors, with fire or panic bolts, which open from the inside when the body weight is pressed against them is desirable. The cellar or basement must not be used as a storeroom for inflammable or combustible material.

Stairways should be made of fire-proof material and should be separated from the corridors by fire-glass doors. Wherever possible, self-closing fire-proof doors should also be available on each floor to separate the stairways from the rest of the building. The stairways should be sufficient in number to permit the building to be emptied in three minutes or less. They should be located conveniently and at two or more ends of the building. Each stairway should be adequately lighted and should lead directly to the street. Artificial lights should be available for dull or dark days and for evening use.

Corridors should also be made of fire-proof or fire-resistant materials and should lead directly and conveniently to the stairways. In elementary schools the main corridor should be 10 feet wide and the secondary corridors not less than 8 feet. In high schools, the corresponding dimensions are 12 and 10 feet respectively. Corridors should be free of obstructing materials and should be well lighted.

The *protection* of children *against* potential *fire* is one of the most essential requirements in the design, construction, and operation of school buildings. The school building should be made of fire-proof or fire-resistant

materials, should have multiple exits, stairways, and corridors, and each exit should be properly marked and each corridor provided with one or more fire extinguishers. One fire extinguisher should be provided for every 2,000 square feet of floor area. An automatic fire sprinkler system should also be available. Fire gongs should be loud enough to be heard in every room, laboratory, and workshop, and fire drills should occur with sufficient frequency to train the children in the orderly and rapid egress from the building. The school should also be connected directly with the municipal fire alarm system. Where special fire escapes are provided they should be properly marked and all windows abutting upon or below them should be made of wired glass. Finally, care must be exercised to avoid a serious fire hazard through the improper storage of inflammable or combustible materials.

Classrooms should be rectangular in shape, attractive in appearance, and conveniently located with regard to the stairways, exits, drinking fountains, and toilets. Each classroom in the elementary schools should provide a minimum floor area of 15 square feet and a minimum of 200 cubic feet of air space per child. In high schools, the minimum requirements are 15 to 18 square feet of floor area and 200 to 250 cubic feet of air space. The amount of glass area in each classroom should vary from one-fifth to one-fourth of the floor area according to the latitude and the presence or absence of light obstructions. Windows should be located on one side of the room only and should permit the light to enter from the left when the children are seated. Windows should be from 3 to 3.5 feet from the floor, should extend close to the ceiling and should be made of clear glass. The distance between windows should not exceed 12 inches.

The *standard illumination* for classrooms and library rooms in elementary schools is six-foot candles at each desk without objectionable glare and shadows. The amount of light required however should be adjusted to the nature of the work being performed. Artificial lighting should be semi-indirect or indirect, and sufficient outlets — 6 to 9 — should be available in each classroom to give the required amount of illumination.

The *shades* should be made of light, translucent materials, should be properly adjusted to each window and should be hung from the center of each window. In this way, any portion of the window may be shaded without darkening the room unnecessarily. In order to darken rooms opaque shades should also be provided.

Individual seats and *desks* should be provided. These should be adjustable, and more important still, they should be adjusted to the needs of the individual child. Movable seats and desks are preferable to those that are fixed. Single pedestal seats are also preferable as they facilitate cleaning the floor. The top of the desk should slope about 15 degrees, and the desk should be so adjusted that when the child is in writing position, the shoulders are parallel to the floor. When seated, the feet of each child should rest squarely on the floor and the knees should be at right angles.

The *heating system* should be ample in capacity to provide a temperature varying between 67° and 70° F. in all classrooms, laboratories, shops, and assembly halls, and the relative humidity should be about 50 per cent.

In the cloak rooms, toilet rooms, corridors, and stair halls, the temperature may be allowed to vary between 65° and 70° F., while in the gymnasium and indoor playrooms the temperature should be maintained between 60° and 65° F.

Drinking facilities should be in the form of bubbling fountains. The common drinking cup should not be tolerated, and even where individual cups are in use at the beginning of the school year, they become common cups before long. The bubbling fountains however should be of the desirable type. Any type that prevents the lips or mouth from coming in contact with the orifice is considered satisfactory. In the elementary schools, one bubbling fountain should be provided for every 50 to 75 children, and in the high schools one for every 75 to 100 children. Bubbling fountains should never be located in the toilet rooms but should be placed in corridors and other convenient places.

Separate *toilet rooms* for boys and girls, located at opposite ends of the school building, should be provided on each floor. The kindergarten children should have separate toilets convenient to their classroom. The toilet rooms should be adequately lighted and ventilated and the walls should be made of non-absorbent material. The window area should represent at least 20 per cent of the floor area. All entrances to toilets should be properly screened. The toilet floor should be made of impervious material and should be properly drained to permit flushing at regular intervals. Individual toilet compartments with light swinging doors should be provided. The toilet seats should be U-shaped and should be made of durable, non-absorbent materials which are poor heat conductors. Each toilet bowl should be provided with individual flushing facilities. Toilet paper racks and paper should also be provided.

The number of toilet fixtures required as suggested by the White House Conference on Child Health and Protection is as follows:

Number of Pupils	Girls' Toilets	Boys' Toilets	Boys' Urinals
100	7	4	5
200	12	7	9
300	16	9	13
400	19	11	15
500	21	12	17
600	24	13	19
700	26	15	21
800	29	17	23
900	32	18	25
1,000	34	19	27
2,000	59	32	48

The *urinals* should be made of non-absorbent materials which can be easily cleaned. Toilet seats should be of suitable height to meet the needs of the age group they are designed to serve.

Washing facilities should be located in the toilet rooms and should consist of washbowls, hot and cold water, sanitary soap dispensers, and in-

dividual paper towels with a receptacle for those that have been used. At least one washbowl for every 20 to 25 children should be provided. The soap used should be either in liquid or powdered form and obtained from special dispensers. Bars of soap which can be used in common should be avoided.

It is needless to say that classrooms, laboratories, workshops, toilet rooms, corridors, offices, and all other parts of the school plant should be kept thoroughly clean and free of objectionable odors. All cleaning should be performed while classes are not in session. Floors may be cleaned by sweeping or by the use of vacuum cleaners, the latter being more desirable. Where sweeping is employed, brushes should be used instead of brooms and the floors should be oiled or waxed, about three times a year. Where the floors are made of impervious materials, they can be cleaned by washing and mopping. Toilet rooms require special consideration and must be mopped or flushed frequently.

The school building should be surrounded by lawns and shrubs and where the land available permits, some trees as well. Care should be taken to minimize the amount of dust and dirt tracked into the school by providing cement approaches to the entrances and scrapers and door mats to remove the dirt from shoes. The area surrounding the air intake for the ventilating system should also be free of dust and dust creating surfaces. In this way the amount of dust introduced into each classroom will be considerably diminished.

Although the requirements of the teaching staff have not been discussed, it is understood that adequate and satisfactory toilet, washing, drinking, and lunch room facilities should be provided. Special rest rooms for both sexes, where male and female teachers are employed, should also be available.

A complete *sanitary inspection* of each school building should be made by a properly qualified person at least once and preferably twice a year. This person — the school physician, school nurse, or sanitary inspector — should have special training to enable him to detect sanitary defects and to make suitable recommendations for their correction or elimination.

CHAPTER XXVII

PUBLIC HEALTH ASPECTS OF CHRONIC DISEASE

The rise in importance of chronic diseases. — Since the latter part of the nineteenth century, remarkable progress has been made in the prevention and control of disease, the prevention of premature mortality, and the prolongation of the average expectancy of life. In 1880 the average expectancy of life at birth was approximately 40 years; in 1935 it is approximately 60 years. However, this gain in average longevity is due almost entirely to the prevention of infant and child mortality and to the conquest of certain communicable diseases.

Since the beginning of the twentieth century, infant mortality rates have been reduced 60 to 80 per cent, and a marked curtailment has occurred in the mortality among children during the preschool and school periods. In 1900 the mortality from diphtheria, for example, in the ten original states that constituted the U.S. Mortality Registration Area at that time was 40.4 per 100,000 population, while in 1932, it was only 2.5 per 100,000 population. Similarly, the death rate from typhoid fever in the original registration states was 31.3 per 100,000 population in 1900 and only 1.1 in 1932. Tuberculosis, which was the leading cause of death at the beginning of the twentieth century, with a death rate of 195.2 per 100,000 population for the original registration area, showed a death rate of 58.7 in 1932. Excellent progress has likewise been made against diarrhea and enteritis, malaria, hookworm, scarlet fever, smallpox, and other diseases — the control of which is dependent upon the control of the environment or the use of specific biological products. In all other diseases little or no progress has been effected. Influenza and pneumonia still take their annual heavy toll in human life; poliomyelitis runs its terrifying course through our communities with little or no effective opposition; and the venereal diseases are still very prevalent.

While much remains to be done to bring certain communicable diseases under control, the significance of the non-communicable diseases, the so-called chronic or degenerative diseases, has in-

creased remarkably during the period under discussion. The control of these diseases does not depend on the conquest of the environmental factors affecting health nor on the use of biological agents such as sera and vaccines. Effective control of these diseases apparently depends largely on hygienic living, initiated at birth and even during the prenatal period, and followed faithfully throughout the life span of the individual; and also on the prompt recognition and early intelligent treatment of the chronic disease as soon as symptoms appear. Thus, the control of chronic disease is a personal rather than a community or environmental problem, and one that must be attacked by individual initiative rather than by mass action against a defective environment.

Is the control of chronic disease a public health problem? — That the consideration of chronic diseases is a legitimate subject for a treatise of this kind is apparent for the following reasons. First, because the leading causes of death at present are the degenerative or chronic diseases such as organic heart disease, cancer, nephritis, cerebral hemorrhage and apoplexy, and diabetes, and their control and prevention represent a public health problem of equal magnitude to the control of the diseases that are spread by contact infection, by insects and rodents, and by defective water, milk, and food supplies. Second, because over 60 per cent of all deaths now occur after age 45, and of this total nearly two-thirds are accounted for by the chronic diseases enumerated above. During the eighties of the past century, chronic diseases made up only one-third of all the deaths occurring in Massachusetts, but at present they are responsible for two-thirds of all the deaths occurring in this state. Third, because the disability is invariably prolonged, the economic loss to the individual and the community is great, and the social problems created, such as relief, hospitalization, clinic, and other public diagnostic facilities, swell the cost of governmental operation. Finally, because there are certain preventive aspects to the consideration of chronic disease, such as hygienic living and the intelligent use of available facilities for diagnosis, guidance, and treatment, which come within the scope of the health education program of a modern and progressive health department.

Since the toll of chronic disease is heaviest after age 55 to 60, the question might properly be raised whether it is desirable to organize a program of prevention and control at considerable gov-

ernmental expense. After all, death has not been conquered yet, and every person must look forward to the ultimate end as he approaches the present average life span. Is much to be gained in attempting to prolong the life of the worn out human machine, when its life work is over? The answer to these questions cannot be given in one word, for it is a complex of reason, emotions, and hope, but the conclusion must be to attempt to bring the chronic diseases under more effective control. In the first place, chronic diseases begin to take their toll as early as age 40, when the individual is of great importance to his family, his profession or occupation, and his community. Second, many individuals, even beyond age 60 are capable of rendering effective and worthwhile service to their fellow men. At a time when mental maturity must be greatest, when the richness of life's experiences is at flood tide, it is sheer waste of precious human material to permit chronic disease to cut off such lives prematurely. Again, since there are certain preventive aspects to chronic disease which can be exercised early in life, there is no reason why such prevention should not be employed and the average life span prolonged to at least threescore years and ten. The essential aim is to defer premature death and to make it possible for each individual to contribute his best to his day and generation. Finally, as long as human ties and affection persist, as long as human suffering is capable of evoking sympathy and assistance, just so long will society refuse to countenance complacently chronic illness and premature death. Under the circumstances, it is no wonder that the Massachusetts State Legislature in 1926 ordered the hesitant State Health Department to initiate a program for the relief and control of cancer, one of the chief of the chronic diseases.

Are chronic diseases more prevalent today? — One of the debatable questions is whether such chronic diseases are really more prevalent today than they were fifty years ago. The assertion is often made that since the public health movement has saved innumerable people from premature death from such diseases as typhoid fever, diarrhea and enteritis, diphtheria, scarlet fever, and tuberculosis, such individuals have lived beyond the average life span of 40 years which prevailed in the eighties of the past century, and have entered the later age groups where the chronic diseases begin to take their toll. The death rates from chronic disease are always higher in communities having a high proportion of older

people than in communities where the proportion of younger people is higher than usual or where the age distribution of the population is normal.

Since the beginning of the twentieth century a marked change has occurred in the age distribution of the population in the United States which is destined to have a profound effect on the general and specific death rates of the future. Since 1920 immigration has been greatly restricted, birth rates have fallen to a point where they are only slightly in excess of the prevalent death rates, and the death rates from most of the communicable diseases have been greatly reduced. The result has been that while the population of the United States between 1900 and 1930 has increased by 62 per cent, the population over 45 has increased by more than 100 per cent, or from 13,500,000 to 28,000,000 approximately. In other words, while persons over 45 constituted only 17.7 per cent of the population of the United States in 1900, they comprised 22.8 per cent of the population in 1930. Accordingly it is argued, it should not be surprising to find the death rate from the degenerative diseases of later life on the increase.

Another argument often presented to explain the increase in chronic disease is that these diseases are diagnosed more readily and accurately today. In the first place, physicians are better trained; second, they see more cases of chronic disease and are therefore able to recognize them more readily; third, there has been so much agitation about the increasing prevalence of chronic disease, that both physician and patient are more mindful of the appearance of early symptoms; and fourth, improved diagnostic aids have been developed in the form of laboratory procedures, highly trained experts, and increased clinic and out-patient department services. These reasons, it is maintained, also help to account for the increase in the prevalence and mortality from chronic disease.

Whether changes in the age distribution of the population and increased accuracy of diagnosis explain entirely the increase in cases and deaths attributed to chronic disease has been the subject of much study and discussion. Some students of the subject believe that there has been not only an apparent but a real increase in the prevalence of chronic disease. Thus, Schereschewsky, of the U.S. Public Health Service, is of the opinion that in the case of cancer, two-thirds of the increased prevalence must be consid-

ered real. With this view, Bigelow and Lombard of the Massachusetts Department of Public Health are inclined to agree.

Whether or not the changes in the tempo of living ushered in by the automobile have had any effect on the prevalence of certain chronic diseases is very difficult to say. Certainly peaceful, serene living is less common than must have been the case a generation or two ago. The hectic pace of daily life at present, the dashing from one place to another, the overburdened programs of many individuals, the keen competition for a living, the innumerable human contacts which a person has in one day, made possible by the conquest of space and time, the ever-present noises, the gay round of exhausting social activities at the end of the day, the multiplication of so-called recreational facilities such as the moving picture theaters, the public dance halls, the radio, etc. — all these factors must make for mental and physical strain which may well pave the way for certain degenerative diseases. On the other hand, the machine age has shortened the work day, has theoretically provided more leisure, and has freed the individual from exhausting and prolonged physical labor. These factors make for better health and greater strength, but it is very doubtful whether they offset the debilitating effects of the wear- and tear-factors enumerated earlier.

Average expectation of life today. — While there has been a marked prolongation in the average expectation of life since 1880 due to the development of the modern public health movement, there has not been any increase in the absolute life span of man. As in days past, few individuals at present live 100 years. In fact, the average expectancy of life at ages 50 to 60 today is slightly less than it was in 1880. Efforts are being made, however, to control premature mortality in the later age groups of life so that the average span of life may approximate the biblical prediction of threescore years and ten. The present average expectancy of life at different ages is recorded in Table 43 on page 538.

Chronic diseases the leading causes of death today. — The present significance of chronic diseases can be studied in at least two ways. First, by comparing the mortality rates for these diseases with those for other causes; and second, by studying the prevalence of these diseases and evaluating their social and economic significance. Both types of data are now available. The mortality statistics can be obtained for the U.S. Registration Area,

TABLE 43

Average Expectation of Life for White Persons by Age and Sex in the United States Mortality Registration Area for 1929, Based on the Mortality Data for 1929–1931 *

Age in Years	Expectation of Life in Years	
	Males	Females
0	59.31	62.83
1	62.12	64.99
2	61.73	64.55
3	61.06	63.85
4	60.29	63.06
5	59.47	62.22
10	55.03	57.70
15	50.46	53.03
20	46.07	48.55
25	41.81	44.25
30	37.57	39.99
35	33.36	35.74
40	29.25	31.53
45	25.30	27.40
50	21.54	23.41
55	17.99	19.60
60	14.73	16.05
65	11.79	12.83
70	9.22	9.98
75	7.03	7.58
80	5.27	5.66
85	3.94	4.22
90	2.88	3.11

from the careful analyses of the Statistical Division of the Metropolitan Life Insurance Company, and from the current scientific literature on chronic diseases. The morbidity data concerning these diseases and their social and economic significance are now available through the recent sickness surveys of the Massachusetts Department of Public Health and other similar investigations. The results of the Massachusetts studies have been published recently (1933) by Bigelow and Lombard in an excellent contribution entitled *Cancer and Other Chronic Diseases in Massachusetts.*† Some of the data presented in this volume are reproduced and discussed in this chapter.

Some idea of the leading causes of death in the United States today can be obtained from the following table. Tuberculosis,

* *Statistical Bulletin,* Metropolitan Life Insurance Company, v. XV, No. 4, April, 1934, p. 9.

† Published by Houghton Mifflin Company, Boston.

normally considered a chronic disease, which was the leading cause of death at the beginning of the present century, has now been relegated to sixth place. Organic diseases of the heart are now the leading cause of death, with cancer, nephritis, cerebral hemorrhage, and other chronic diseases following in importance. Pneumonia alone remains among the "Big Six" as a representative of the importance of the acute communicable diseases as causes of death. But, while the death rates from pneumonia and tuberculosis have been diminishing from 1929 to 1933, the mortality rates for the other diseases listed in the table have either increased or remained stationary.

TABLE 44

LEADING CAUSES OF DEATH IN A PORTION OF THE U.S. MORTALITY REGISTRATION AREA, HAVING A POPULATION ON JULY 1, 1933 VARYING BETWEEN 88.1 AND 94.8 MILLIONS

(Rates per 100,000 Population) *

CAUSE OF DEATH	1933	1932	1931	1930	1929
Diseases of the heart [1]	224.8	219.5	211.7	209.6	215.1
Cancer, all forms	102.6	100.7	97.6	96.5	95.5
Nephritis, acute and chronic	80.8	84.4	83.7	88.0	90.7
Cerebral hemorrhage, apoplexy	79.2	79.3	78.5	78.9	79.6
Pneumonia, all forms	69.4	77.4	82.0	83.2	92.5
Tuberculosis, all forms	56.5	60.4	64.8	68.2	72.8
Diabetes	21.5	21.7	20.3	19.1	18.8

Data for pneumonia, tuberculosis, cancer, and diabetes are for 28 states; nephritis, 27 states; diseases of the heart, 26 states; and cerebral hemorrhage, 25 states.

[1] Diseases of the heart include pericarditis, acute endocarditis, chronic endocarditis, diseases of the myocardium, diseases of the coronary arteries and angina pectoris, functional and other diseases of the heart, and aneurysm.

The increasing significance of chronic diseases as a cause of death, and therefore as a current public health problem, may be further illustrated by the following mortality data for Massachusetts from 1900 to 1930.

In an excellent paper entitled "Favorable Aspects of Heart Disease" presented before the American Public Health Association meeting at Indianapolis on October 9, 1933, Dublin and Armstrong of the Metropolitan Life Insurance Company, state that "on a conservative estimate, the number of persons suffering from heart disease in the United States is probably close to two millions."

* *U.S. Public Health Reports*, v. 49, No. 18, May 4, 1934, p. 562.

TABLE 45

SPECIFIC DEATH RATES PER 100,000 POPULATION IN MASSACHUSETTS—CHRONIC DISEASES, 1900–1930 *

YEAR	HEART DISEASE[1]	NEPHRITIS	CANCER	DIABETES
1900	159.5	80.4	71.2	11.8
1901	163.4	82.7	73.1	11.2
1902	161.3	81.3	74.3	13.1
1903	174.0	90 5	76.8	14.0
1904	190.8	88.0	81.7	14.1
1905	187.4	86.0	83.3	14.2
1906	190.8	84.0	85.5	13.7
1907	207.5	89.4	89.0	15.1
1908	187.3	81.5	89.8	13.9
1909	177.6	88.0	90.6	15.5
1910	180.3	91.0	90.0	17.0
1911	170.6	103.4	92.8	18.3
1912	202.3	85.0	93.5	16.7
1913	204.4	94.0	98.6	17.4
1914	210.3	94.0	98.5	17.3
1915	193.5	94.2	100.2	18.2
1916	232.4	93.4	106.8	21.0
1917	235.8	93 1	107.7	20.6
1918	205.1	103.8	107.8	17.9
1919	180.9	95.7	107.2	16.5
1920	192.3	94.2	116.1	20.6
1921	198.5	83.2	118.9	19.9
1922	223.0	82.8	117.9	24.0
1923	229.3	87.0	119.9	21.4
1924	218.4	83.2	126.2	19.2
1925	240.1	77.7	128.0	19.9
1926	264.8	97.7	130.4	20.4
1927	249.3	91.0	131.9	20.4
1928	269.5	90.0	134.4	22.3
1929	273.7	84 6	134.7	23.7
1930	267 2	87.4	136.8	24.0

[1] Heart disea includes pericarditis, myocarditis, endocarditis, angina pectoris, and allied diseases.

In New York City, at least one out of every eight of the chronically ill was found to be suffering from heart disease, while in Massachusetts, Bigelow and Lombard estimate the number of heart cases to be 84,000, or one out of every seven of the chronically ill.

Under existing conditions of mortality, Dublin and Armstrong conclude that one out of every five white males born will even-

* From data presented by Bigelow and Lombard in *Cancer and Other Chronic Diseases in Massachusetts*, 1933.

tually die of organic heart disease, while for white females the ratio is even slightly higher. In fact, the chances of dying from heart disease are not only greater than for any other single cause, but exceed those for tuberculosis and cancer combined. This probability increases with advancing age, so that one out of every four females alive at age 45, under present conditions, will die from heart disease, while one out of every four males alive at age 50 will die from heart disease.

The prevalence of chronic disease in Massachusetts as determined by recent sickness surveys conducted by the Massachusetts Department of Public Health is indicated by the data presented in the following table. By far the most important disease from the standpoint of prevalence, is rheumatism, with heart disease, arteriosclerosis, nephritis, apoplexy, diabetes, and cancer following in consecutive order.

TABLE 46

ESTIMATED CASES OF CERTAIN CHRONIC DISEASES IN MASSACHUSETTS, 1929–1931

Disease	Estimated Number of Cases
Apoplexy	16,000
Arteriosclerosis	64,000
Cancer	(5,000) 11,500[1]
Diabetes	15,000
Heart disease	84,000
Nephritis	21,000
Rheumatism	138,000
Pulmonary tuberculosis	(4,000) 15,000[1]
Mental	(5,000) 25,000[1]
24 other diseases	206,000
Total	558,000

[1] Probable actual number of cases.

Age and sex distribution of chronic disease in Massachusetts. — That chronic disease is an extremely important cause of disability and death has been amply demonstrated by the statistical data presented earlier in this chapter. Its full significance becomes more apparent however if its prevalence and mortality are analyzed by age and sex and if the social and economic problems created by disabling disease and premature death are fully appreciated. Chronic disease does not kill immediately. Instead the stricken individual is subjected to prolonged illness which uses up his

available financial reserve and which incapacitates him for remunerative work over a long period of time. Bigelow and Lombard estimate that the annual financial toll due to chronic disease in Massachusetts is at least $80,000,000, or twice the annual cost of running the state government.

But the real cost of chronic disease can never be fully estimated. Attacking as it does during the prime of life when the individual is of greatest value to his family, much suffering is created, heavy expenses are incurred, the careers of growing children are of necessity altered, the welfare lists are swelled, out-patient department attendance is increased, and other social and community problems are created. While disease and death cannot be postponed indefinitely, the object of the public health campaign is to defer them until old age begins its rapid disintegrating effects. At present these degenerative influences appear with amazing frequency at age 40 approximately, and increase rapidly in the age groups up to 70. It is in this span of human life that the preventive aspects of chronic disease must be successfully established.

The significance of chronic disease in Massachusetts by age and sex may be obtained by studying the data in the following table.

TABLE 47

SPECIFIC MORBIDITY RATES FROM CHRONIC DISEASE PER 1,000 POPULATION IN MASSACHUSETTS, 1929–1931, DISTRIBUTED ACCORDING TO AGE AND SEX *

AGE GROUP	MALES	FEMALES	TOTAL POPULATION
Under 20	19.9	17.1	18.5
20 39	51.5	67.2	60.0
40–44	152.1	189.9	171.9
45–49	172.6	252.0	214.2
50–54	208.4	291.4	251.0
55–59	269.5	348.6	310.3
60 64	322.1	421.1	374.6
65–69	374.1	491.6	437.3
70–74	530.9	589.4	562.7
75–79	614.9	701.4	661.7
80 and over	673.6	729.9	707.5

Organic heart disease. — Having discussed the significance of chronic diseases in general, each of the more important chronic diseases will now be considered separately, emphasis being placed

* From data presented by Bigelow and Lombard in *Cancer and Other Chronic Diseases in Massachusetts*, 1933.

on the preventive aspects of each disease. The question may well be asked whether anything can be done to prevent the ravages of the degenerative diseases of early and late adult life, since such changes must be inevitable in the wake of the daily wear and tear of the human machine, but the situation is far from hopeless and in fact much preventive work has been done already.

Since organic heart disease is the most important single cause of death, it will receive first consideration. In this discussion "organic diseases of the heart" will include not only the "functional and other diseases of the heart" which are responsible for approximately 89 per cent of all the deaths from heart disease, but also pericarditis, endocarditis, myocarditis, and angina pectoris. According to this definition, the trend in the death rate from organic heart disease in the U.S. Mortality Registration Area for a recent 20-year period is indicated in the following table.

TABLE 48

DEATH RATES FROM ORGANIC DISEASES OF THE HEART PER 100,000 POPULATION IN THE U.S. MORTALITY REGISTRATION AREA, 1911 TO 1931

YEAR	DEATH RATE	YEAR	DEATH RATE
1911	157.1	1922	164.6
1912	159.9	1923	173.8
1913	155.8	1924	176.5
1914	159.7	1925	185.7
1915	165.7	1926	199.5
1916	168.7	1927	196.0
1917	171.7	1928	208.2
1918	170.1	1929	210.8
1919	146.7	1930	213.5
1920	159.1	1931	212.7
1921	156.3		

The decline in the mortality rates from 1919 to 1922 is doubtless due to the high mortality from influenza that occurred among cases of heart disease during the severe epidemic of 1918–1919.

Geographical variation in heart disease mortality. — The mortality from heart disease is not uniform throughout the world nor even in the United States. In this country the death rates in the Southern and Rocky Mountain states are distinctly lower than the rates in the Pacific, New England, and Middle Atlantic states. Similarly, the rate for Japan is low in comparison with the rates prevailing among the other great nations of the world. The death

rates in cities are higher than for rural sections, and in England it is reported that the death rates from heart disease are higher in counties near the sea.

Analyses of heart disease mortality by age and sex. — Although the consideration of the specific death rates for any disease over a long interval of time indicates the trend in the death rate for that cause, its value is exceedingly limited. It is only when the specific death rate is analyzed by age, sex, color, nativity, and other factors that the varied aspects essential for a complete picture of the disease can be obtained. This has been done recently (1933) for heart disease by Dublin and Armstrong who analyzed the mortality data for the millions insured in the Industrial Department of the Metropolitan Life Insurance Company for the period from 1911 to 1932.

This analysis discloses much that is encouraging. Instead of mounting rapidly for all ages, the death rates from heart disease, have actually come down during certain periods. In the age group from 1 to 24 for example, the death rates among white persons have been reduced nearly 50 per cent.

In the age group from 25 to 44, the mortality among whites is also encouraging. From 1911 to 1918, there was a steady decline in heart disease mortality; the rate then fell sharply until 1922, after which it rose again. In spite of this rise, however, the death rates have remained approximately 25 per cent below the level prevailing at the time of the 1918–1919 influenza epidemic.

For the later age groups the heart disease mortality is not so encouraging, thus demonstrating that an increasing death rate from heart disease is a phenomenon of middle life and old age. In the age group 45 to 54, the death rate among white males is still lower than those which prevailed in the pre-influenza period. But in the succeeding age groups, the present death rates from organic heart disease among white males have already exceeded the rates of the pre-influenza period. For white females in these age groups, the situation is better, for the prevailing death rates are lower than those which occurred prior to the 1918 pandemic of influenza. This is true even for the age group 65 to 74, and is pronounced for the age groups 45 to 54 and 55 to 64. Also of interest is the fact that among white females the death rates from organic heart disease are lower than for white males in every age group except 1 to 24; but even here, the difference is negligible.

Causes and types of heart disease. — Heart disease differs from the specific bacterial diseases, for it is not a single entity but rather a complex of many factors, both etiological and pathological. The malady may be the result of rheumatic infection, syphilis, arterial degeneration, renal disease, or certain other minor causes, or a mixture of these conditions. About 10 to 15 per cent of the cases are the results of congenital defects and malformations, thyroid disease, acute infections such as diphtheria, cardiac neuroses, trauma, and certain undetermined causes.

While rheumatic fever affects from one to two per cent of the entire population in the United States, its incidence varies with geographical location. It is more prevalent in New England and the Middle Atlantic states than in the south, southwest, or the Pacific northwest. It is less frequent in the tropics than in the temperate regions. In the vicinity of New York, Dublin and Armstrong estimate that rheumatic fever is responsible for about 30 per cent of all cases of heart disease. Under age 20, four out of five cases of heart disease have rheumatic origin, and if the cases of unknown etiology are excluded, then nine out of ten cases have rheumatic origin. Between 20 and 29, two-thirds of all cases have a rheumatic background; between 30 and 39, more than half; and between 40 and 49, one-fourth of all the male heart cases and one-third of all the female cases. After age 50, rheumatic fever plays a relatively small part in the causation of heart disease.

Syphilis, another important cause of heart disease, is responsible for one out of every 20 cases. Under age 30, it is relatively uncommon as a cause of heart disease mortality except for a negligible proportion of children with congenital syphilis. In females the percentage is low except between the ages of 40 and 50 when it is responsible for about 10 per cent of all heart disease cases among them. In adult males the problem is more acute. Between the ages of 30 and 39, about 10 per cent of all cases of heart disease are due to syphilis, and between ages 40 and 59, the proportion is increased to about 20 per cent. In males after age 60, syphilis accounts for about 10 per cent of the cases of heart disease.

By far the largest proportion of heart disease cases is due to senescence or arteriosclerosis. This type of heart disease is quite rare before age 40. Between 40 and 49, one-sixth of all cases of heart disease is of this type; between 50 and 59, the proportion is increased to one-half, and after age 60 to about three-fourths.

Another cause of heart disease that deserves special mention is hyperthyroidism, which in women between 30 and 49 is a frequent cause of heart symptoms. In the Pacific northwest, where goiter is quite prevalent, Coffen (1929) found that this disease is responsible for 6.1 per cent of heart cases.

In general, however, Dublin finds that in a thousand cases of heart disease, 25 per cent are due to rheumatic fever, 40 per cent to arteriosclerosis, 10 per cent to syphilis, and about 10 per cent to other causes.

The development of these conditions in the individual gives rise to injury of the heart structure and causes such diseases of the heart as endocarditis, myocarditis, angina pectoris, and functional disturbances. Endocarditis, or inflammation of the internal serous membrane of the heart, is caused chiefly by microbic diseases such as rheumatic fever and other streptococcic infections, and syphilis. These infections often affect the heart valves. Mitral valve disease, for example, is chiefly, though not exclusively, of rheumatic origin and is found most commonly in youth and middle life. It affects females more extensively than males, the incidence being about 50 per cent higher. Aortic valve disease is also of microbic origin, but the responsible organism is more frequently the Treponema pallidum, the cause of syphilis. This type of heart disease is most common in middle life and affects males about three times as frequently as females.

The most important type of heart affliction is myocardial disease. The principal manifestation of this disease is enlargement of the heart. The cause of cardiac enlargement is heart strain, the chief factors of which are hypertension and valvular disease. Valvular disease as noted above is principally of rheumatic origin, but the hypertensive cases which are far more numerous are due to degeneration and fibrosis resulting chiefly from coronary disease. Such cases are practically limited to middle life and old age, and more particularly to the latter.

While mortality from valvular heart disease has diminished perceptibly from 1923 to 1932, particularly in the age group under 25, but noticeably also in the age group 25 to 44, the mortality from myocardial disease, or disease of the heart muscle, has steadily mounted during the same period. In the age group 25 to 44, the death rate for this type of heart disease has increased about 100 per cent for males and 67 per cent for females. The

increases in middle life and old age, where this type of heart disease is most prevalent, have also been as great.

The contrast between the trends in the two types of heart disease is striking. Valvular diseases of the heart which affect young people particularly and which are microbic in origin have given way because of the progress in the control of the acute infectious diseases, rheumatic fever, and even syphilis. The decline in syphilis mortality among white men has been real and substantial. The progress made against heart disease in the early age groups and even up to the age of 50 has been due chiefly to the conquest of the microbial diseases enumerated above. Here is a field of prevention which can be explored much further and which belongs quite properly to the sphere of activity of the progressive health officer.

While the mortality from myocardial disease has shown an increase, there is really very little cause for alarm. This type of heart disease affects the later age groups particularly and is the result of senescence or degeneration, or the wearing out of the human machine. If the average life span of man is prolonged by the conquest of the communicable diseases and the effective control of the environment, then we may reasonably expect an increase in mortality in the diseases associated with old age. Very little prevention can as yet be practised in this field. By resort to the thorough annual physical examination for adults particularly, beginning with early middle life, early senescent changes may possibly be detected, and the individual can probably prolong his life and comfort by adhering closely to the rules of hygiene. Adequate rest, proper diet, sufficient sleep, satisfactory elimination of waste products, lack of worry, the adoption of a serene philosophical plan of existence should help to aid these injured veterans of life through the later age periods which bacteriology, sanitation, and other aspects of modern science have helped them to attain.

Rheumatic fever. — Rheumatic fever, a precursor of heart disease, is believed to be bacterial in origin, the inciting agent being a member of the streptococcus group. It is preeminently a disease of childhood, affecting those in poorer economic circumstances particularly. Insufficient food or a diet lacking in essential nutritional elements may play a part in paving the way for the development of the disease. Its maximum incidence occurs before

the age of 10, and after 12 the tendency to infection begins to diminish. During childhood rheumatic fever is more frequent among females.

According to careful studies made to determine the time elapsing between the onset of rheumatic fever and the development of valvular heart disease, the average interval is approximately four years, the minimum being one year and the maximum eight years. It has also been determined that the average duration of fatal disease — the period between infection and death — is approximately 17 years.

Since rheumatic fever is an important cause of heart disease and is theoretically preventable, efforts to bring it under effective control are being made in increasing measure. Control of the disease depends not only on the prompt recognition of all cases and the provision of suitable medical treatment, but likewise on the elimination of all focal infections and emphasis on adequate bed rest. In fact, sanatoria or convalescent homes have been recommended as suitable instruments for the effective treatment of rheumatic fever. Wherever possible, removal to a subtropical climate is desirable, since the symptoms are greatly ameliorated when this occurs. Emphasis should also be placed on adequate and proper nutrition, the elimination of housing evils, and the general control of the environment in order to maintain the vital resistance of the individual against potential rheumatic fever infection.

Hypertension or high blood pressure. — Hypertension or high blood pressure is also responsible for heart disease, particularly among people in middle life and the later age groups. It is also associated as a contributory causative agent in deaths resulting from apoplexy and Bright's disease, two of the leading causes of death today. The cause of hypertension is still unknown. Because of its comparative absence among the Chinese and other Mongolians, and also among primitive races — people who do not live under constant nervous strain, excitement, and worry as so many Americans do — it is believed to be a product of our modern Caucasian civilization. Once the condition develops to any degree, it usually persists throughout life. It develops in some people but not in others, and heredity is believed to be a predisposing factor.

The control and prevention of high blood pressure are probably

intimately associated. They depend on strict adherence to the rules of hygienic living. The thorough annual physical examination made by a competent physician and including the various laboratory aids for proper diagnosis is essential to detect hypertension early. The hygienic régime calls for rest, relaxation, ample sleep, the development of a calm and philosophical outlook on life, and the avoidance of overeating, overdrinking, overexercising, and other excesses which may affect the health of the individual.

Arteriosclerosis. — Arteriosclerosis or hardening of the arteries is a widespread condition occurring among all races, affecting both sexes, and appearing at all ages. Its prevalence is naturally greater in later life because of its association with senescence. Although it affects both sexes, males exhibit arteriosclerosis to a much greater degree in the early age groups than do females. This is due apparently to the greater strain to which males as a rule are subjected.

The cause of arteriosclerosis is not clearly understood in most instances. The hardening process resulting from the deposition of lime salts is preceded by a softening of the arterial wall. When arteriosclerosis sets in, the artery becomes stiff and the lumen is narrowed. This puts a greater strain on the heart, causing it to pump harder and faster. Accordingly, arteriosclerosis is associated with organic heart disease in middle life and during the later age periods.

The signs and symptoms of arteriosclerosis are numerous and they may appear in any part of the body. They exhibit themselves mostly through the functional disturbance of the organ or tissue affected by the reduction in the flow of blood. Among the signs indicating arteriosclerosis are the whitening of the hair, the loss of elasticity in the skin, the appearance of apoplexy and other brain disturbances, the development of eye cataracts, the appearance of deafness resulting from the diminished blood supply to the inner and middle ears, the elongation and stiffening of the aorta, the development of angina pectoris and coronary thrombosis, and the appearance of the symptoms of Bright's disease. The most serious effects of arteriosclerosis are on the heart, brain, and kidneys.

There is no effective curative treatment for arteriosclerosis; only alleviation. Rest and diminished activity of the affected organ are essential. Prevention revolves around the basic require-

ments of hygienic living, some of the essentials of which were outlined in the discussion of hypertension.

Cancer. — Cancer, the second most important cause of death, is another of the chronic diseases which affect people in the middle and later age groups particularly. At present (1934) it is responsible for about 12 per cent of all male deaths over 30, and 16 per cent of the female deaths in the same broad age group. It is primarily a disease of late adult life, only 2 per cent of the cases occurring in the age group under 30. The greatest incidence of cancer is found in the age group 60 to 69.

Cancer affects all animals, domestic and wild, as well as man. It is found in all parts of the habitable world regardless of climate, among all races, among all economic and social groups, regardless of dietary differences or intellectual attainment. Females show a higher incidence of cancer than males, the difference occurring in the age group 30 to 69, the reason being the greater prevalence of cancers of the breast and the female genital organs at this time.

The cause of cancer is still unknown. It is known, however, that cancer is a non-communicable disease, and while the disease itself is not hereditary, a certain predisposition to it is apparently transmissible through heredity. It often develops after prolonged chronic irritation. It may affect any organ or tissue of the body. At first, cancer is a localized disease, and if promptly diagnosed and properly treated at this time, the disease may be cured. External cancers can be detected more readily than cancers of the internal organs so that prompt diagnosis of the latter does not occur as frequently. If the cancer is not cured in the early stages, some of the cancer cells wander off to other parts of the body, establishing new and often inaccessible growths, which make the disease incurable. These secondary, spreading growths occur with varying rapidity, depending on the type of the original cancer and its malignancy. Innocent or benign tumors remain in one place and are seldom fatal. Once removed, they do not recur.

Distribution of cancer mortality in the United States. — Although cancer is found in all parts of the United States, its mortality and apparently its incidence vary considerably with the section of the country. The death rate from cancer is especially high in the New England and Middle Atlantic states, less so in

the middle west and far west, and least of all in the southern and southwestern areas. The highest death rates are more than three times as great as the lowest. This marked difference in cancer mortality may be due in part to variations in the age distribution of the population, and in part to variations in expert diagnosis, but there are probably other factors not yet disclosed, which also account for this unusual phenomenon. The mortality rates from cancer which prevailed in 1929, arranged by states in the order of magnitude, are presented in the following table.

TABLE 49

Death Rate from Cancer and Other Malignant Tumors per 100,000 Population in the U.S. Mortality Registration Area for 1929, Arranged in the Order of Magnitude

Order	State	Rate	Order	State	Rate
1	Maine	140.8	25	Michigan	94.2
2	Rhode Island	135.7	26	Kansas	91.1
3	New Hampshire	133.9	27	Nevada	88.8
4	Massachusetts	132.9	28	Montana	87.5
5	Washington, D.C.	132.8	29	Idaho	78.8
6	Vermont	129.5	30	Virginia	70.0
7	New York	122.1	31	Utah	69.3
8	Connecticut	119.5	32	Florida	68.7
9	California	118.1	33	North Dakota	67.4
10	Minnesota	116.8	34	Kentucky	67.3
11	Wisconsin	111.4	35	Louisiana	65.2
12	Iowa	111.1	36	Tennessee	59.2
13	Maryland	109.6	37	West Virginia	57.8
14	Missouri	108.7	38	Arizona	56.1
15	Oregon	107.8	39	Oklahoma	51.4
16	New Jersey	107.6	40	North Carolina	51.3
17	Washington	107.3	41	Alabama	51.0
18	Illinois	107.2	42	Mississippi	50.7
19	Indiana	107.1	43	Georgia	50.2
20	Ohio	104.8	44	New Mexico	49.7
21	Pennsylvania	103.6	45	Wyoming	47.9
22	Delaware	103.3	46	South Carolina	43.6
23	Colorado	99.9	47	Arkansas	42.8
24	Nebraska	98.6			

In 1929, Texas and South Dakota were not part of the U.S. Mortality Registration Area. Since then, these states have been admitted.

Increasing significance of cancer as a cause of death. — While data have been presented earlier in this chapter to show that the death rate from cancer has been mounting steadily in recent years, the increasing significance of cancer as a cause of death is

demonstrated even more effectively by reviewing the situation in Massachusetts since 1850.

TABLE 50

DEATHS AND DEATH RATES PER 100,000 POPULATION FROM CANCER FOR MASSACHUSETTS, 1850–1929 *

YEAR	CANCER DEATHS	DEATH RATES	RATIO OF CANCER DEATHS TO TOTAL DEATHS
1850	152	15	0 91
1855	219	20	1.05
1860	317	26	1.37
1865	367	29	1.40
1870	508	35	1.79
1875	618	37	1.87
1880	906	51	2.64
1885	1,089	56	2.85
1890	1,356	61	3.06
1895	1,677	67	3.49
1900	1,993	71	4.12
1905	2,502	83	4.94
1910	3,039	90	5.77
1915	3,773	102	6.92
1920	4,400	115	7.75
1925	5,168	128	10.10
1929 [1]	5,698	135	11.16

[1] Three year average centering on 1929

In the course of 80 years, the cancer death rate in Massachusetts has evidently increased ninefold, and the ratio of cancer deaths to total deaths increased about twelvefold. While part of this increase can be explained on the basis of variations in the age distribution of the population at both periods, and also to the great improvement in the diagnosis of cancer which the passage of time has witnessed, much of it, cannot be accounted for on this basis and must be considered a true or real increase.

Cancer deaths by age and sex. — Reference has already been made to the fact that cancer mortality under 30 represents less than 2 per cent of the total mortality from cancer, and that there is a greater toll among females than among males. That the marital state bears a causal relationship to the high death rate from cancer among females is evident from the fact that unmarried females suffer less from cancer. Single females, however, exhibit higher

* Arranged from data presented by Bigelow and Lombard in *Cancer and Other Chronic Diseases in Massachusetts*, 1933.

death rates from cancer than single males. Single females also have lower death rates from cancer of the genital organs than from cancer of the breast, while the reverse is true for married females. This is doubtless due in part to the accepted view that unrepaired cervical lacerations resulting from childbirth are responsible for many cancers of the uterus.

The variations in cancer mortality by age and sex are presented in the following table and they demonstrate that cancer as a cause of death is especially significant in the middle and later adult age groups.

TABLE 51

PERCENTAGE DISTRIBUTION OF CANCER DEATHS BY AGE AND SEX IN THE U.S. MORTALITY REGISTRATION AREA FOR 1929

AGE GROUP	MALES	FEMALES	TOTAL
Under 10	0.3	0.2	0.5
10–19	0.3	0.3	0.6
20–29	0.6	0.8	1.4
30–39	1.4	3.4	4.8
40–49	4.4	8.5	12.9
50–59	9.2	12.7	21.9
60–69	13.5	14.3	27.8
70–79	11.3	10.8	22.1
80 and over	3.6	4.2	7.8
Unknown	0.1	0.1	0.2
Total	44.7	55.3	100.0

Cancer mortality by location and sex. — Although cancer affects all organs and tissues of the body, certain types of cancer figure more prominently in the mortality records. These cancers affect the internal organs and are discovered usually only after they have become moderately advanced. It is estimated that delay in the diagnosis and treatment of cancer is responsible for at least one-fifth of the cancer deaths occurring at the present time. In the Massachusetts cancer studies made by Bigelow and Lombard, it was found that among the cancer patients attending the state cancer clinics, the median duration of the disease prior to consulting a physician was six months, and the median duration of the disease prior to coming to the cancer clinic was one year. The time elapsing varies with the location of the cancer, the time being longer where the internal organs were affected.

It was also found that about one-fifth of all the cancer patients at the state clinics had never consulted a physician prior to the first clinic visit. Since the average untreated case of cancer lives only twenty-one months approximately, the importance of early diagnosis and prompt, effective treatment becomes apparent. It is estimated that if this were done in Massachusetts, at least 1,200 deaths from cancer could be prevented annually, and that for the country as a whole the saving would be over 30,000 lives per year. This would represent a saving of 25 per cent in cancer mortality.

TABLE 52

PER CENT DISTRIBUTION OF CANCER MORTALITY BY LOCATION AND SEX IN THE U.S. MORTALITY REGISTRATION AREA FOR 1929

LOCATION	MALE	FEMALE	TOTAL
Buccal cavity	2.6	0.6	3.2
Stomach and liver	18.6	15.4	34.0
Peritoneum, intestines, and rectum	7.1	8.1	15.2
Female genital organs	0.0	14.3	14.3
Breast	0.1	9.0	9.2
Skin	1.6	1.0	2.6
Other and unspecified organs	14.6	7.0	21.6
Total	44.6	55.4	100.0

From the preceding table it is apparent that cancer of the stomach and liver represents the most important single cause of cancer mortality, contributing about 35 per cent of the total mortality from cancer; cancer of the intestines and rectum, about 15 per cent; cancer of the female genital organs, about 15 per cent; cancer of the breast, about 10 per cent; while cancer of the mouth cavity and cancer of the skin are each responsible for about 3 per cent of the cancer mortality. From the standpoint of the interval of time elapsing between the onset of symptoms and the time of death, cancer of the skin shows the longest duration and cancer of the oesophagus the shortest. Breast cancers have a duration next to cancer of the skin, while cancers of the stomach group have a very short duration. The more hidden the cancer the less likely the discovery and the shorter the period between diagnosis and death.

The variation in cancer mortality according to the organ and sex affected can be expressed in terms of death rates. Recent data, obtained according to this method of analysis, are available

for Massachusetts and are incorporated in the following table. The higher death rates among males from cancer of the buccal cavity and cancer of the stomach and liver, and among females from cancer of the genital organs and the breast, are the noteworthy facts of this analysis. The Massachusetts studies have confirmed the previously accepted view that buccal cavity cancer is more prevalent among excessive users of tobacco. However, cancer of the buccal cavity may and does also occur among nonsmokers.

TABLE 53

CANCER MORTALITY PER 100,000 POPULATION BY LOCATION AND SEX FOR MASSACHUSETTS FOR 1929 AND 1930

Location	Male	Female	Total
Buccal cavity	8.1	1.5	4.7
Stomach and liver	41.9	35.9	38.8
Peritoneum, intestines, and rectum	23.3	29.0	26.2
Female genital organs		34.5	17.7
Breast	0.5	29.2	15.2
Skin	2.4	1.8	2.1
Other and unspecified organs	40.9	20.5	30.4
Total	117.1	152.4	135.2

The control of cancer. — The control of cancer is another instance illustrating the truth of the oft repeated expression that "knowledge is power." In this disease as in many others, time is an exceedingly important factor in effective control. In fact, since the etiology of the disease is still unknown, and since a specific cure has not been discovered, cancer control is dependent entirely on early diagnosis and prompt and effective treatment. The effectiveness of knowledge in the control of cancer is illustrated by the observation that in 1930, when cancer represented the second most important cause of death in the general population, it ranked fifth as a cause of death among American physicians. Furthermore, the Massachusetts studies have demonstrated that the foreign born and their first generation exhibit higher death rates from all chronic diseases, including cancer, than do those of native-born parents. Similar observations made in England are explained not on the basis of nativity, but on the basis of poverty. Since poverty is often associated with ignorance, it is fair to conclude that lack of knowledge plays an important part in this

unfavorable situation among the foreign born and their first generation of descendants.

As early diagnosis is essential for the control of cancer, it is highly important that the people in general and the medical practitioner in particular should be familiar with the early symptoms of the disease. There are three cardinal symptoms which are suggestive of cancer and whenever one or more appears, competent diagnostic advice should be obtained. The appearance of a chronic lump in any portion of the body, the presence of chronic unhealed sore, or the occurrence of an unaccustomed discharge from any orifice of the body are the three symptoms, any one of which is suggestive of cancer. Knowledge of these facts and of the importance of seeking competent medical advice promptly should be disseminated among the people through the great variety of publicity channels now in existence.

The first line of defense against cancer must of necessity be the private practitioner, for it is to him that the patient first turns for assistance in times of distress or physical uncertainty. Unfortunately, however, most physicians in a state like Massachusetts see on the average about three cases of cancer per year and these of different organs, so that regardless of the thoroughness of his student training in cancer diagnosis, it is impossible for him to be an expert in the diagnosis of cancer under these circumstances. Cancer control therefore requires expert diagnosticians aided by the examinations of competent pathologists, and such facilities must be provided if the private practitioner is to be an important element in the early diagnosis of cancer. After cancer is diagnosed, it must be treated promptly by surgery or with X-rays or radium in order to bring it under control.

The Massachusetts cancer program. — That cancer incidence and mortality were increasing in significance had been appreciated for a long time, but since the disease was non-communicable, health officers refused to recognize it as a public health problem. But in 1926 the Massachusetts State Legislature by special resolve and without stimulation by the health authorities, committed the State Department of Public Health to a program of cancer control. In this it even antedated the official action of the American Public Health Association which in 1927 officially took the stand that the control of cancer represented a legitimate and important current public health problem.

The purpose of the Massachusetts cancer program, briefly stated, is to stimulate earlier and more adequate treatment of the disease through education, clinic and hospital services, and further study and thus to lower the cancer death rate. To this end 12 cancer clinics operated by the State Department of Public Health and functioning successfully as consulting and diagnostic centers, have been established in strategic locations throughout the state. In addition, a State Cancer Hospital was opened at Pondville in 1927. This was accomplished by taking over and renovating an institution built in 1915 for the care of alcoholics and narcotic addicts, but which had not been in use for some years. The hospital had 115 beds and was fully equipped with suitable operating rooms, deep X-ray machines of the latest type, a gram of radium, an electro-surgical unit, good laboratories, a library, and in short everything that was needed to conduct a modern and approved hospital. The hospital acts as a diagnostic and training center, and has evidently filled such a need in the state that a long waiting list for admission has been created. All patients are admitted regardless of economic or social status. Unfortunately fully 25 per cent of the patients admitted are already moderately advanced cases of cancer for whom a permanent cure is no longer possible, so that the principal function of the hospital to date has been alleviation. Those who have left the hospital alive have stayed on the average 17.6 days, while the average length of stay for terminal cases has been 30.8 days. Among the former group, those suffering from buccal cancer have stayed the shortest period of time while those having intestinal cancer have stayed the longest. It is hoped that with the machinery already in operation and the great impetus to effective cancer control work which the official program in Massachusetts has given to non-official agencies, in time a marked curtailment in cancer mortality particularly in the middle adult age groups will become manifest.

Misconceptions concerning cancer. — Even in this day of comparative enlightenment and scientific knowledge, certain widespread popular misconceptions will develop where a disease like cancer is concerned. This is likely to occur in any disease as universal as cancer, especially if the etiology is still unknown and a specific cure is yet to be found. It was the case in tuberculosis before the light of science dispelled the veil of ignorance and

superstition, and a somewhat similar situation exists with regard to cancer today.

Based on the knowledge already in existence it is probable that cancer is not the result of constipation or chronic auto-intoxication; or the consumption of meat, fish, sugar, white bread, or alcohol; or the excessive use of salt; or even because of a general vitamin deficiency. Furthermore, while worry and mental distress are undesirable and are not conducive to good physical health, they do not have apparently any etiological relationship to cancer. Similarly the moderate use of tobacco has no relationship to cancer of the buccal cavity. The presence of unclean, ragged teeth in the mouth, the use of ill-fitting dental plates, and syphilis — these factors play a much more important rôle in the development of cancer in the buccal cavity.

And yet cancers have been produced experimentally in the lower animals. This may be accomplished by chronic irritation, particularly with coal tar. A recent contribution from England indicates that the real agent in coal tar responsible for the production of cancer is dibenzanthracene. Few other chemical agents than coal tar and its derivatives have ever been incriminated as far as cancer etiology is concerned. About the only one thus classified has been arsenic which is known to be able to produce cancer of the skin. Industrial chemical workers who handle acids and other corrosive substances such as caustic soda and lime, as well as a variety of other chemical agents often suffer serious burns and other skin afflictions but rarely develop cancer of the skin in consequence.

Nephritis or Bright's disease. — Nephritis, another of the chronic diseases and an important cause of mortality, is a disease of the kidneys, the function of which is to remove the waste products from the body. The disease occurs in two forms, acute and chronic, the former occurring chiefly in children and young adults primarily as a result of a respiratory infection such as tonsilitis or scarlet fever, while the latter occurs usually beyond the age of 35 and is the result of high blood pressure and general arteriosclerosis. In the case of acute nephritis, the disease develops after the respiratory infection has subsided and is characterized by unusual pallor, slight puffiness of the face or feet, the diminished flow of urine and the appearance of albumin in this excretory product. Most patients recover from this infection within

a few weeks, especially if adequate bed rest, the free use of liquids, and proper dietetic treatment is prescribed and followed. A few cases develop into chronic nephritis usually either because the disease was not recognized or did not receive proper treatment, and in rare instances the patient may die.

Chronic nephritis is primarily not a disease of the kidneys at all, but a disease of the small arteries occurring all over the body. As a result of these sclerotic changes occurring in the arteries, the supply of blood to the various organs of the body including the kidneys is diminished and their nutrition is impaired. As a result, degeneration of the affected organs occurs. If the brain is the organ primarily affected, apoplexy will result. On the other hand if circulation through the heart is the primary impairment, then organic heart disease develops; but if the kidneys are the organs principally affected, then chronic nephritis occurs. The disease is always associated with high blood pressure. The prevention and control of chronic nephritis as far as we know, are identical with the requirements for the prevention and control of high blood pressure, and these have been discussed earlier in this chapter.

Arthritis or chronic rheumatism. — Chronic rheumatism or arthritis is a disease which interferes with the free motion of the joints, causes considerable pain and discomfort, and has the highest incidence of all the chronic diseases. In the Massachusetts studies on chronic disease it was found that one out of every thirty-three of the population suffered from chronic rheumatism. Although its incidence is very high, its mortality is exceedingly low. It is a disease that cripples but rarely kills. It is prevalent throughout the world. Females in Massachusetts show twice as much rheumatism as males. The disease seems to be more prevalent under rural than urban conditions, perhaps because the medical facilities in cities are superior and more adequate. The highest incidence occurs among people in the lowest economic groups. In England, during one year, the relief societies alone distributed over ten million dollars for aid to people suffering from rheumatic diseases, and these same diseases in one year caused a million weeks of idleness. They have therefore great economic and social significance as well as public health importance.

Chronic rheumatism is quite different from acute rheumatism or rheumatic fever discussed earlier in this chapter. The latter

comes on quite suddenly with sharp pain and inflammation and swelling of the joints, lasts a few weeks and then subsides, usually leaving the joints as free as ever and the patient often apparently as well as ever, although the heart is frequently affected. Chronic rheumatism on the other hand usually comes on slowly and only one joint may be stiff for a day or two without any swelling or inflammation. Later other joints are affected, the stiffness does not wear off, and swelling comes on gradually.

Chronic rheumatism is of two main types, one usually affecting children and adults under forty, the other, adults over forty. The former is usually a little more acute in its onset and its progress a little more rapid. If it is unchecked, it is more crippling, and the bones and muscles affected tend to waste away. The second type results in the deposition of lime about the edges of the joints, often producing little bunches or overgrowths about the end joints of the fingers as a first disturbing symptom. The first type is due to lowered resistance resulting from communicable disease, excess fatigue, undue exposure to cold and dampness, constipation, an improper diet, too little exercise, bad tonsils and bad teeth, or a combination of several of these factors. The second type may also have its origin in the causes just enumerated but it is less likely to be microbial in origin. On the other hand, the gradual ageing of the body, the insidious onset of arteriosclerosis, results in less perfect functioning of the organs and tissues with the resulting deposition and accumulation of lime in the joints.

As far as we now know, the prevention and control of chronic rheumatism depend on strict adherence to hygienic principles. The earliest symptoms should cause the individual to seek competent medical aid. In addition all focal infections should be eliminated, the nutrition should be adequate and satisfactory for the needs of the body at each age, elimination of body wastes must be regular and satisfactory, excess fatigue and worry should be avoided, and there must be adequate emphasis on rest, sleep, fresh air, adjusted exercise to meet the needs of the individual, and the other hygienic practices essential for healthy living. After the disease has developed to any appreciable degree, surgical, mechanical, and medical aid must be enlisted for effective treatment.

Diabetes. — Diabetes, the last of the chronic diseases to be considered here, is a condition that develops when the body ceases

to receive the benefit of the sugar that is produced from food. During health this sugar is used to supply fuel for the muscles and to keep the body warm. The utilization of the sugar is marvelously regulated during health by the secretion from one of the glands of the body, the pancreas, and more particularly from that portion of it known as the Islands of Langerhans. This gland secretes a substance known as insulin which performs the sugar-regulating function. The lack of insulin in the body causes the sugar produced from the food to collect in the blood and to escape unused in the urine. When this condition results, diabetes is said to have developed.

As noted earlier in this chapter, the mortality from diabetes is not only high but it has been increasing with the passage of time. In view of the discovery of insulin in 1922 and its widespread use in the treatment of diabetes, the steadily mounting death rate from this disease represents an anomaly. Its importance from a public health point of view is attested not only by its high and steadily increasing death rate but by its widespread incidence. Dr. E. P. Joslin of Boston, one of the recognized authorities on diabetes, estimates that there are at least 1,400,000 individuals in the United States who suffer from diabetes. The death rate from this disease in the United States is materially higher than that prevailing in other countries, and there is a marked variation in the mortality from diabetes among the cities in this country. In 1932, when the death rate from diabetes in the United States was approximately 20 per 100,000 population, the death rate in McKeesport, Pa., was only 1.8, while that of Williamsport, Pa., was 56.5.

The cause of diabetes is unknown. It is rather rare among children, but its incidence increases with advancing age. About two-thirds of the cases occur after age 40. It occurs more frequently among the obese than among those of normal or less than normal weight. In patients over 20 years of age, Joslin reported that 77 per cent were 11 per cent or more overweight at or before the onset of the disease, while only 2 per cent of the patients were 11 per cent or more underweight. Diabetes is more common in women than in men. Heredity is also an important factor in diabetes, the hereditary characteristic behaving as a recessive rather than a dominant factor. Two diabetics should not marry and have offspring, because theoretically all the children will become diabetic. If a diabetic marries a non-diabetic, but the latter comes of a dia-

betic family then half the children may be expected to develop diabetes. If two non-diabetics of diabetic families marry, 25 per cent of the children should develop diabetes. Finally, if a diabetic marries a non-diabetic of a non-diabetic family, then none of the children should develop diabetes.

The prevention of diabetes depends in a large measure on controling the amount of food consumed and thus avoiding obesity or overweight. This is especially true for adults. Again the importance of regulating one's own hygienic régime to meet the particular needs of the individual is emphasized. However, once the disease develops, control measures must be introduced and maintained as long as the situation requires. Control is based fundamentally on two factors, one, the regulation of the diet, and more particularly the carbohydrate and fat components, in order to prevent overeating, and second, the use of insulin. Since the use of insulin and the more scientific regulation of the diet, the life of diabetics has been greatly prolonged. In former years one out of every five diabetics died during the first year of the disease. Now only one in twenty-five die as speedily. Whereas in former years it was an unknown experience for diabetic patients to come under medical supervision for the first time after reaching age 70, today, that observation is becoming more frequent.

The subcutaneous administration of insulin by hyperdermic inoculation is a disadvantage associated with its use. If given by mouth it is completely destroyed by the digestive juices long before it can be absorbed into the blood stream. Most patients now learn how to administer insulin to themselves, and they live twice as long as they did before, often exceeding the life expectancy they might have had without diabetes. Furthermore, they enjoy an independence and productiveness which must add a great deal of pleasure to their lives. Not all diabetics have to continue the use of insulin for the remainder of their days once its administration is begun. While some must use it always, others can get on without insulin from the very start and some can give it up after a suitable time, the pancreas in such cases, having recovered some of its lost function to secrete insulin. The effectiveness of the dietary control and insulin administration is determined by the presence or absence of sugar in the urine.

Certain serious dangers are associated with diabetes which can be effectively controlled by intelligent care and treatment. One

is diabetic acidosis and coma, and another is diabetic gangrene. The first is due to disregard of the dietary restrictions, or to neglect in the use of insulin, or to the development of fever. Fortunately, many of the coma cases can now be saved by insulin, but prior to the discovery of this agent, the development of diabetic coma meant death in a few hours or days. In the case of fever following infection, and in order to prevent the development of coma, insulin is administered either in larger doses or more frequently.

Diabetic gangrene is caused by poor circulation in the feet and the greater susceptibility to slight injuries which pass unnoticed by the older diabetics. Gangrene seldom occurs in young diabetics. The condition is entirely preventable and as gangrene takes such a heavy toll among diabetics, it is important to disseminate this information. Prevention is dependent on scrupulous cleanliness of the feet and other parts of the body, and the prompt detection and suitable treatment of any skin injury, no matter how slight.

By requiring a medical examination and urinalysis prior to accepting an applicant as a suitable risk, the life insurance companies have done much to make people aware of these protective mechanisms to personal health. In the case of the Metropolitan Life Insurance Company, every individual insured for $5,000 or more is eligible annually for such an examination without cost. An annual health inventory is good protection especially if it is performed by competent examiners and with suitable laboratory aids, for such examinations represent the very basis for the early detection and prompt treatment of the chronic diseases. For adults approaching forty who desire to live the normal life span and to continue to do effective work, this should prove to be sound advice.

CHAPTER XXVIII

ORGANIZATION FOR PUBLIC HEALTH ADMINISTRATION IN THE UNITED STATES

Local governmental unit, the basis of state and Federal powers. — The development of the art and science of sanitation, personal hygiene, and preventive medicine has stimulated the creation of the necessary governmental machinery required to spread the benefits of these health conservation activities among the entire population. The form of government in the United States being either Federal, state, or local, it was only natural that the administration of public health activities should be divided among these various agencies. While the professional functions of each agency are largely similar in scope, each is limited geographically in its sphere of influence and activity. The Federal public health agencies are interested primarily in public health problems that have interstate significance, the solution of which lies outside the province of any single state. The state health departments have jurisdiction over public health problems within the boundaries of each state, and in addition, they aid, supervise, guide, and stimulate the local public health activities. The actual administration of local public health work is performed by the local health department. The power of the latter is ultimate and greater than that of the state or Federal health agencies. The state government obtains its powers from the local communities, and the Federal Government from the various states in the Union. Because of these conditions, it is logical to begin the consideration of "public health administration" from the standpoint of the local community.

Powers of the local governmental unit in matters affecting the public health. — Through authority granted by the state legislature, the local governmental unit is responsible for the control of local health conditions. In order to administer this control effectively, each state authorizes the organization of local boards of health or other appropriate health organizations, and each board is empowered to adopt rules and regulations consistent with existing state health laws and sanitary codes. Each board is also

authorized to hold hearings, to issue licenses, and to perfect the organization required to protect and promote the public health of the local community. It is thus vested with unusual powers over the lives and properties of the people within its jurisdiction, and these must be employed with reason and discretion and only for the purpose of safeguarding the public health. This is usually the case. The health department advises, guides, and educates and accomplishes its purpose in these ways. Only occasionally must it exercise its great police powers to bring some recalcitrant person into harmony with the requirements for the public welfare, for local health ordinances are invariably sustained in the law courts.

Development of the local administrative health unit to its present state. — As early as 1678, Boston and Salem, Mass., adopted regulations for the control of smallpox, but the statutory requirement calling for the establishment of local boards of health in Massachusetts and providing them with adequate powers was not enacted until 1797. The first local board of health was organized in Baltimore in 1793. Philadelphia followed in 1794, Newburyport, Mass., in 1797, and New York and Boston in 1799. Boards of health were called into being and their powers greatly extended from time to time, largely as a result of public health surveys which disclosed conditions that required correction.

The history of the public health survey and its effect on the development of local public health administration were ably presented by Dr. Haven Emerson in "Public Health Diagnosis" — the Fifth Sedgwick Memorial Lecture, delivered in Cambridge on April 8, 1927. The famous British sanitary survey performed by Mr. (later Sir) Edwin Chadwick was published in 1842; the equally famous sanitary survey of Massachusetts was published by Mr. Lemuel Shattuck in 1850; and the report of the Council of Hygiene and Public Health of the Citizens Association of New York upon the Sanitary Conditions of the City was published in 1865. The next important sanitary survey formed a part of the *Pittsburgh Social Survey of 1907*, and was initiated by the Charities Publication Committee and financed by the Russell Sage Foundation. In the study dealing with the typhoid fever situation in Pittsburgh and its relation to polluted water, Professor Sedgwick played an important part. Following this survey, the New York Bureau of Municipal Research, the Russell Sage Foundation, the U.S. Public Health Service, and various philanthropic and educational institu-

tions entered the field of public health diagnosis and made available scores of detailed, scientific reports on municipal health department practice in the United States. In this work the Department of Biology and Public Health of the Massachusetts Institute of Technology, founded by Professor Sedgwick, played a leading rôle. In 1920 the American Public Health Association, through its newly created Committee on Municipal Health Department Practice (now the Committee on Administrative Practice) entered the field of public health surveys partly for the purpose of making available authentic information on municipal health department practice in the United States, and partly as a means of stimulating municipalities to greater health achievement. In 1920 and 1921, the Committee on Municipal Health Department Practice surveyed 83 cities in the United States which had a population of 100,000 or more in 1920, and published its findings in 1923 in *Public Health Bulletin No. 136*, issued by the U.S. Public Health Service. The report presented the public health situation then found in the large cities in the United States, and an outline of an ideal health department for city of 100,000 prepared by Professor C.-E. A. Winslow and Dr. H. I. Harris. Thus, for the first time a yardstick was made available whereby the adequacy of public health service in the larger cities could be measured.

Two other nation-wide surveys of municipal health department practice occurred during the next few years which have had a profound effect on public health administration in the United States. The first was the resurvey of public health practice in the larger cities in 1923 conducted by the U.S. Public Health Service in coöperation with the Committee on Administrative Practice of the American Public Health Association. The results were published in 1926 as *Public Health Bulletin No. 164*. The second was the carefully planned and effectively executed *Health Survey of 86 Cities* conducted by the American Child Health Association in 1924, the report of which was published in 1925. The first of these surveys included the hundred largest cities in the United States, which in 1920 had a population of 70,000 or more. The survey of the American Child Health Association confined itself to the medium sized cities which in 1920 had a population between 40,000 and 70,000. One of the significant contributions of this study was the formulation of a plan of health department organization and activity for the city of 50,000 population. Later, Professor I. V.

Hiscock formulated a plan of organization for administering the health work in cities of 20,000 population. This was based on a series of public health surveys of small cities, chiefly in Connecticut. Thus, separate plans were now available for health department organization and activities in the large, medium sized, and small cities of the United States, and by this means the progressive health officer or the interested citizen could ascertain whether his community was providing adequate public health service.

Still another development resulted from those nation-wide studies of public health conditions in urban communities which has had a far-reaching effect on municipal health department practice in the United States. In March, 1925, after much expert consideration and some experimentation in the field, the first edition of the *City Health Appraisal Form* was issued by the American Public Health Association. This represented an evolution of the score card for municipal health activities which was prepared in 1923 by Dr. Charles V. Chapin, the distinguished health officer of Providence, R.I. Since 1925, the *City Health Appraisal Form* has undergone three revisions, and the fourth edition which appeared in March, 1934, consists of eleven items with corresponding relative weights or values. The total score is 1,000 and the actual score in any case is a measure of the extent to which a community has provided the public health machinery and personnel necessary to protect and promote the public health. The *City Health Appraisal Form* measures the quantity and not the quality of public health work performed in a community. In most cases, however, a high rating on the *Appraisal Form* coincides with superior quality of health service. Since 1929, the *Appraisal Form* has been used as a basis for comparison in the health conservation contests conducted by the U.S. Chamber of Commerce among large, medium sized, and small cities. The field work on which each rating is based is performed by a representative of the Committee on Administrative Practice of the American Public Health Association. The contests, conducted annually, have been helpful in stimulating the interest of local chambers of commerce in public health work and in creating a demand for more adequate health service in each community.

The items included in the latest issue of the *City Health Appraisal Form* and their relative weights are given below. Each item

is rated on the basis of 100 points, and after the rating is completed it is multiplied by a relative weight to obtain the final or adjusted value. The relative weights for the items enumerated below total only to 9.50, the remaining 0.50, or 50 points on the basis of 1,000 for the total score, being added if each of the eleven sections in the *Appraisal Form* attains half of its total possible score. This provision is designed to encourage the development of a properly balanced health program.

TABLE 54

ITEMS AND RELATIVE WEIGHTS OF THE "CITY HEALTH APPRAISAL FORM" IN 1934

ITEM	RELATIVE WEIGHT
I. Common Services	
A. Vital statistics	0.45
B. Laboratory	0.60
II. Preventable Disease Activities	
A. Acute communicable diseases	1.55
B. Venereal diseases	0.65
C. Tuberculosis	0.90
III. Activities for the Promotion of Hygiene of the Individual	
A. Maternity hygiene	0.90
B. 1. Infant hygiene	0.90
2. Preschool hygiene	0.90
C. School hygiene	1.10
IV. Sanitation Activities	
A. General sanitation	0.80
B. Food and milk	0.75
Total	9.50

In addition to the above items, the *City Health Appraisal Form* includes several items which are not scored. These are the Control of Cancer, Heart Disease, and Mental Hygiene. Popular Health Instruction which was included as a separate section in previous editions of the *City Health Appraisal Form* is omitted in the latest edition and instead is now distributed among the other sections. An *Appraisal Form for Rural Health Work*, based on extensive rural health studies made in recent years, is also now available.

Development of county health units. — The health organization in any part of the United States is determined by the governmental administrative unit in existence. In the eastern and north-central sections of the United States, health departments or boards

of health were organized on the township basis. In the other areas, notably the south, southwest, and far west, the county basis of organization is employed. There are approximately 2,950 counties in the United States, five-sixths of which are rural in character. Since approximately 50 per cent of the total population of the United States still live under rural conditions, rural health represents one of the important current public health problems. This is particularly true as many rural communities are poor and are unable to provide the public health personnel and activities which will enable them to have the public health protection enjoyed in urban communities. But the rural community is no longer as thoroughly isolated as it was prior to the construction of good roads and the almost universal use of the automobile. While these developments have increased the exposure of the rural resident to communicable disease, they have brought him a varied and fresh food supply, health information, and the invaluable services of the state, Federal, and philanthropic health agencies. Public health work in rural communities has dealt primarily with the improvement of rural sanitation and the elimination of typhoid fever, dysentery, hookworm, and malaria.

The development of rural health work in the United States on a scientific and progressive basis was not the result of local initiative and enterprise. On the contrary, it resulted from the activities of the U.S. Public Health Service, the U.S. Children's Bureau, the various state departments of health, the National Tuberculosis Association, the American Red Cross, and some of the great philanthropic foundations like the Rockefeller Foundation, the Commonwealth Fund, and the Milbank Memorial Fund. There is some difference of opinion as to which county in the United States was the first to establish a health department with a full-time health officer in control. Such county health departments were organized simultaneously for the first time in 1911 in Washington, North Carolina, and Kentucky. Table 55 on page 570 illustrates the growth of county health organizations in the United States.

The reduction in the number of full-time county health units in 1933 is due to the abandonment of the county organizations that were established recently following drought and floods in the valley of the Mississippi River and its tributaries. In some states, like Alabama and Mississippi, the county is the unit of all local public health activity.

TABLE 55

GROWTH OF FULL-TIME COUNTY HEALTH ORGANIZATIONS IN THE UNITED STATES

YEAR	NUMBER OF COUNTY HEALTH UNITS
1915	13
1916	15
1917	30
1918	37
1919	67
1920	124
1921	177
1922	201
1923	230
1924	280
1925	303
1929 (Jan. 1)	461
1932 "	616
1933 "	581

The county health organization is not a complicated health unit. Its personnel consists of a full-time health officer with one or more public health nurses and sanitary inspectors. An appropriation of at least $1.00 per capita per year is usually considered essential to provide adequate health protection, but the annual per capita expenditure is under 50 cents. In most states, however, the state health department supplements the county health service in the fields of vital statistics, laboratory diagnosis, public health engineering, medical inspection, public health nursing, and epidemiology.

The influence which state health departments exert on the organization and conduct of county health work is in most instances very significant. This is accomplished in various ways. In many states, county health organizations are made possible only through state subsidies. This enables the state health department to certify properly qualified applicants for appointment to county positions, to prescribe the program in considerable detail, and to exercise intimate supervision over the activities of the county health department. In addition, it adopts rules and regulations for the county health department to observe, it enumerates the duties to be performed, it specifies the qualifications for local appointees, and it acts as consultant in the various phases of county health work.

District and coöperative health units. — A plan of coöperative health department organization has been evolved in Massachusetts

which provides full-time trained health service in communities too small to afford it individually. The Wellesley experiment, initiated by the Department of Biology and Public Health of the Massachusetts Institute of Technology in 1914 and conducted by personnel trained at that school, brought together a number of small communities into a unit large enough to provide full-time trained public health service. The undertaking has remained in force since its inauguration, although the towns composing the unit have varied from time to time. Under this plan, each town contributes its proportionate share to the budget of the health department, appoints a representative to the Cooperative Board of Health and enjoys the benefits of a high grade, full-time health service. Since 1931, the Massachusetts Department of Public Health with financial aid from the Commonwealth Fund of New York has conducted two interesting cooperative health units in some of the less populous areas of the state as a demonstration of the value of such cooperative effort. One unit is known as the Southern Berkshire Health Unit, comprising fifteen towns, among which are Lenox, Stockbridge, Great Barrington, and Becket. The other, known as the Nashoba Health Unit, is made up of fourteen towns and includes such communities as Ayer and Groton. The headquarters of the first unit are at Great Barrington, and those of the second are at Ayer. Still another cooperative effort in Massachusetts is the Cape Cod Health Bureau of Barnstable County. This was the first county health department to be established in New England. For some years it was subsidized by the U.S. Public Health Service, but since 1933, owing to the necessity of governmental retrenchment, it has been self-sustaining.

The district health plan, operating in Florida, Illinois, Maine, Maryland, Massachusetts, New York, and Pennsylvania, is quite different from the cooperative health units described above. According to this plan, the state is divided into districts, and a district health officer, employed by the state department of health, is placed in charge over each area. He acts as the representative of the state department of health in his district. In this capacity he stimulates the local health units to greater activity and accomplishment, supervises their work, acts as guide and advisor, aids in the control of communicable diseases, and in some cases actually performs the local public health activity in large areas which makes for greater efficiency and effectiveness.

Qualifications of health department personnel. — The efficiency of public health administration in any community does not depend fundamentally on the presence or absence of a board of health or advisory council, but primarily on the professional and personal qualifications of the health officer and his staff. Public health is a separate and distinct profession, the practice of which is based on bacteriology, chemistry, physiology, parasitology, psychology, sanitary science, statistics, medicine, engineering, and other technical and scientific pursuits. It is therefore erroneous to assume that a physician, engineer, or any other person who has not been trained in public health as a profession is qualified to perform the duties of health officer in a satisfactory manner. While public health practice requires the services of physicians in the operation of clinics and the conduct of medical inspections, it also includes the control of the environment, popular and personal health education, laboratory diagnosis, statistical analysis, sanitary inspections, and engineering activities which are usually outside of the scope of medical training. The appointment of a health officer or any other member of the health department staff should not depend on whether he is a physician, engineer, or social service expert, but rather on whether the candidate possesses the necessary professional and personal qualifications for the position in question. It is only in this way that a proper basis for effective public health administration can be assured.

Proper scientific training alone is not the only requirement for effective public health administration. There are other requirements of equal importance. A pleasing personality is indispensable for the successful health officer. The possession of tact and integrity, the ability to speak well and to meet people in an agreeable manner, a knowledge of popular psychology, the ability to formulate intelligent plans, to make sensible decisions, and to direct the work of others, are all essential attributes for the efficient and successful public health administrator. Given such a director, it can be assumed that the selection of the subordinate personnel will be made wisely and with adequate emphasis on professional and personal qualifications.

Effective public health administration also requires freedom from undesirable political interference. In this way each employee may be assured permanent tenure of office unless he is guilty of incompetence. dishonesty, or other justifiable cause for dismissal.

To some extent, politicians have learned that interference with the organization and activities of an efficient department of health is unfavorable to the community welfare and therefore unwise politically. As a result, there is less political interference in health department practice today than ever before. With improvement in the professional and personal qualifications of health department personnel, and the curtailment of political interference, the health department is gradually approaching the status of the school department in professional dignity and security.

For the most effective administration of a health department it is essential that the health officer should be employed on a full-time basis. The employment of a physician or other person on a part-time basis as health officer is undesirable and invariably leads to neglect, inefficiency, and waste. Under such conditions the interests of the health department and the welfare of the local community suffer. Similarly, all the other personnel of the health department, excepting the examining physicians, should be employed on a full-time basis.

The board of health and advisory council. — In order to make its work most effective, the health department, which consists of the health officer and his subordinate personnel, should have the guidance and support of an influential group of local citizens. This requirement is met either through the appointment of a board of health or the creation of an advisory council, or by establishing both groups. The board of health is appointed by the mayor or city manager, while the advisory council may consist of one or more groups organized to aid and advise the health officer and is usually made up of individuals appointed by the health officer himself. Sometimes a health council is formed, which is composed of representatives from the various professional, charitable, social service, and civic groups in the community interested in public health matters but who have no official status. Such organizations as the local medical and dental societies, the visiting nurse association, the local tuberculosis association, the Red Cross, the various charities and relief agencies, the local hospitals, the woman's club, the chamber of commerce and one or more of the business men's luncheon clubs, and other welfare agencies in the community would be represented in this council. Such a council facilitates greater coördination and coöperation in the conduct of the local public health program; it provides an influ-

ential group of local citizens who are familiar with the needs and activities of the health department; it aids in obtaining popular and political support for a well-rounded public health program in the community; and by its support and backing, it stabilizes the health department organization and makes its activities more efficient.

The board of health should be a small group, three or five in number, composed of citizens interested in promoting the public health, appointed by the mayor or city manager, and allowed to serve without pay. Rarely is it possible for all the members of a board of health to be experts in the field of public health. They must be capable of wise judgment and intelligent decisions and they should be representative of the community they serve. They stand between the health department and the mayor, have the power of appointing the health officer and other health department personnel, and may at times interpret the health department activities to the public. They hold regular meetings, usually once a month, adopt regulations for the sanitary code which are not in conflict with the state health laws, hold public hearings whenever necessary, and pass upon the budget, program, and activities of the health department.

The members of the board of health should be appointed for overlapping terms, the longest appointment depending on the size of the board. There should be provision for reappointment or replacement when the term of office expires, and not more than one member should be appointed annually.

The board of health should not be composed entirely or even largely of physicians, for such an arrangement is not representative of the community interests nor of public health practice. On the other hand, one member of the board of health should be a physician so that questions of medical policy may receive adequate and informed consideration. The other members of the board may be chosen from the fields of engineering, education, business, and social or civic welfare. The latter field particularly lends itself to the appointment of a woman and this is highly desirable.

It is better administrative practice for the health officer not to be a member of the board of health, and thus not to have the opportunity to consider and pass upon his own activities. He may serve as clerk or secretary to the board of health, keep a

permanent record of the minutes of all meetings, prepare an agenda of items for consideration at each meeting, and in general, serve as the agent of the board. The board of health should elect annually from its members its own chairman, and he should be eligible for reappointment as long as he serves as a member of the board.

Headquarters of the health department. — The headquarters of a municipal or county health department should preferably be located in the city hall or the county administration building. It is desirable for the health department to be housed in close proximity to the other branches of the city or county government. The facilities should be ample and attractive. In some cities and counties special health center buildings, forming a part of a community center development, have been provided to house all the health department activities. In some of the larger cities, where the wisdom of decentralization has been appreciated, branch headquarters have been organized for every district. This does not eliminate the necessity for maintaining a central headquarters where the basic administrative staff, the division of vital statistics, and the diagnostic laboratory service are housed, but it does make it possible to conduct public health work in a more intimate and direct way in each district. The creation of seven health units in Boston, for example, each a model in pleasing architecture and design, has made it possible to conduct a city-wide public health program on a decentralized basis. More important still, such an arrangement creates a health consciousness in each district which is essential for public cooperation and effective health service.

Organization and activities of a health department. — The activities which make up a modern public health program are common to each governmental unit regardless of size. The organization required varies quite naturally with the size of the community and the funds available. In small communities the staff of the health department will be correspondingly small, and the health officer may in fact be required to perform all or most of the health activities. The *City Health Appraisal Form* serves as an excellent outline of the requirements of a modern public health program. These activities may be grouped for convenience under the following bureaus, but the specific form of organization adopted by any community will depend on local circumstances. Furthermore, since each activity has received adequate

consideration in earlier chapters of this text, the work of each bureau will not be discussed here. The outline alone is presented in order that the student may visualize a proper organization for a modern department of health.

TABLE 56

ORGANIZATION OF A HEALTH DEPARTMENT

1. Bureau of administration.
   A. Division of administration.
   B. Division of public health education.
2. Bureau of vital statistics.
3. Bureau of preventable disease control. (It is assumed that the control of all communicable diseases not specifically mentioned here will be under this bureau.)
   A. Division of epidemiology.
   B. Division of tuberculosis.
   C. Division of venereal diseases.
   D. Division of cancer control.
   E. Division of heart disease control.
4. Bureau of maternal and child hygiene.
   A. Division of prenatal hygiene.
   B. Division of infant and preschool hygiene.
   C. Division of school hygiene and sanitation.
5. Bureau of public health nursing.
6. Bureau of sanitation.
7. Bureau of foods.
   A. Division of milk supplies.
   B. Division of food and drugs.
8. Bureau of laboratories.

Some idea of the staff required to administer a modern public health program in communities of varying size may be obtained by reference to the ideal health departments for large, medium sized, and small cities in the United States mentioned earlier in this chapter, and to the text on *Community Health Organization* by Ira V. Hiscock, published by the Commonwealth Fund of New York in 1932.

State health department practice. — Although the organization of local health units antedated the organization of state health service in the United States, the latter has come to have an important rôle in public health administration in every state of the Union. As a result of Lemuel Shattuck's Sanitary Survey of Massachusetts in 1850, the first State Board of Health in the United States was organized in Massachusetts in 1869. This step

stimulated the organization of similar state health departments throughout the country, and the plan adopted in Massachusetts served as a model for many other states. At first the functions of the state board of health in Massachusetts were advisory in character. The board was to "make investigations," "gather information for diffusion among the people," and "make suggestions as to legislative action." Gradually, however, all state boards of health assumed other functions, many of which are executive, advisory, and supervisory in character, and at present they occupy a unique and influential position in public health administration in each state. Besides Massachusetts, state boards of health were established early in California (1870), in Virginia (1872), and in Maryland (1874). Among the more recent state boards of health to be established are Georgia and Oregon (1903), Idaho (1907), and Texas (1909).

State health department organization varies considerably throughout the United States. This was demonstrated in the Survey of Health Departments of States and Provinces of the United States and Canada for the year 1925 made for the Conference of State and Provincial Health Authorities of North America, which was published in 1929 by the U.S. Public Health Service as *Public Health Bulletin No. 184.* The state board of health form of organization has been abandoned, for example, in Connecticut, Maine, Massachusetts, New York, Ohio, and West Virginia. In each of these states a public health council has been appointed whose function is purely advisory. There is a state commissioner of health who is the executive officer, and who is also a member of the public health council. In Illinois, Michigan, North Dakota, and Pennsylvania there is an advisory council or board instead of a state board of health.

Three states — Idaho, Nebraska, and Oklahoma — have no state board of health or advisory council. Although the law in Tennessee provides for a state health advisory council of five members to be appointed by the governor, the members have not yet been appointed, and the state health officer has full executive power. There are 34 states which have state boards of health, but in two of these — Alabama and South Carolina — the form of organization is unique. In Alabama the state medical association is the state board of health. The association is composed of 150 physicians who act as counselors and who represent the 10 con-

gressional districts in the state, and 143 physicians who serve as delegates and who represent the 67 component county societies of the state medical association. This body elects the state board of censors, which consists of ten men, all of whom must be chosen from the state counselors. The governor is a member and ex-officio chairman of the state board of censors. This body is the acting state board of health.

In South Carolina, the state medical association, together with the state attorney-general and comptroller-general, compose the state board of health. This association elects seven members to be appointed by the governor to constitute an executive committee. The attorney-general and the state comptroller are ex-officio members of the executive committee, and the state pharmaceutical association nominates one member who is appointed by the governor, thus making an executive committee of 10 members. This committee corresponds to the state board of health.

Appointment to membership on a state board of health is made by the governor of the state, with or without the consent of the senate. In eleven states, all the members must be physicians, while in twenty-one states, a certain number of the members of the board must be physicians. Six states — Connecticut, Maryland, New Hampshire, New York, Pennsylvania, and Utah — require that there shall be at least one engineer on the state board of health or public health council. He must be either a civil or a sanitary engineer. Six states specify that a dentist shall be a member of the state board of health; three states require a pharmacist; three states require that one or more women shall be members; Kansas requires one layman and Louisiana, an educator.

The term of office varies, but usually members are appointed for overlapping terms so that a majority of the board will at all times be experienced in handling its affairs. With few exceptions, membership on a state board is honorary, the members being paid traveling expenses and in some instances a modest per diem salary when the board of health is in session. Regular meetings occur monthly in eleven instances and usually four times a year or less in the other cases. The executive power of the state boards of health is vested in or delegated to an officer designated either Secretary of the State Board of Health, state health officer, director of health, or commissioner of health.

The executive officer of health is chosen either by the state

board of health or the governor with or without the consent of the senate or the governor's council. In 39 states he must be a physician. Of the other nine states, four — New Jersey, New Mexico, Virginia, and Delaware — require that he be a sanitarian, four do not have any legal qualifications as a requirement, and in one — Colorado — the only requirement is that the state health officer be a citizen and voter. Sixteen states require that the state health officer be experienced in public health.

Functions of a state department of health. — According to the *American Public Health Association Year Book*, published as a supplement to the *American Journal of Public Health for February, 1934*, the desirable standard minimum functions of a state department of health are as given below. These standards, officially adopted by the American Public Health Association, are based on current state health department practice, and they represent the basic activities of a modern state department of health

1. Supervision of local health activities.
2. Establishment and enforcement of minimum standards of performance of the work of health departments, particularly in respect to communities receiving state aid for public health.
3. Enactment of regulations dealing with sanitation, disease control, and public health, which have the force of law throughout the state.
4. Collection, tabulations and publication of vital statistics for each important political or health administration unit of the state and for the state as a whole.
5. Collection and distribution of information concerning preventable diseases through the state.
6. Maintenance of safe quality of water supplies and control of the character of the disposal of human wastes for all communities of the state.
7. Establishment and enforcement of minimum standards for milk supplies.
8. Prescription of qualifications for certain public health personnel.
9. Maintenance of a central and necessary branch laboratories for the standard functions of diagnostic, sanitary, and chemical examinations; production of therapeutic and prophylactic preparations, and their free distribution for public health purposes; establishment of standards for the conduct of diagnostic laboratories throughout the state; laboratory research in the causes and means of control of preventable diseases.

Organization of the Massachusetts State Department of Public Health. — In order that the reader may obtain a clearer and more definite picture of the structure and functions of a state depart

ment of health, the organization of the Massachusetts Department of Public Health, admittedly one of the best and most progressive in the United States, will be briefly described. It consists of a Public Health Council of seven members, including the Commissioner of Health who must be a physician trained in preventive medicine, and who is appointed by the governor with the consent of his council. The Public Health Council holds monthly meetings and in 1933, was composed of four physicians, a civil engineer, and a layman, in addition to the Commissioner. The term of two members of the Council expires each year, so that a majority of the members remain on the Council even if two new members are appointed.

The state is divided into seven districts with a district health officer in charge of each. The state health department also operates a central diagnostic laboratory at the State House in Boston, a Wassermann Laboratory, the State Antitoxin Laboratory at Forest Hills where some of the accepted biological products are manufactured, the famous Lawrence Sewage Experiment Station where experimentation and research on problems pertaining to water purification, sewage treatment, and shellfish sanitation are still conducted, four large state sanatoria for the treatment of adult and childhood tuberculosis, and the State Cancer Hospital at Pondville.

There are eight divisions in the Massachusetts State Department of Public Health and in 1933, there were 278 employees, technical and non-technical, exclusive of the large staffs associated with the four state sanatoria and the Pondville Cancer Hospital. The detailed organization in 1933 exclusive of the Public Health Council is as follows. The commissioner of health is not only the director of the division of administration but is the executive officer for the entire department.

1. Division of Administration.
   Commissioner of health, one secretary, one epidemiological consultant, and 11 clerks and stenographers.
2. Division of Adult Hygiene.
   One medical director, 2 epidemiologists, 2 social workers, 2 public health education workers, one field epidemiologist, and 15 clerks and stenographers.
3. Division of Biological Laboratories.
   One medical director, one assistant director, 8 chemists and bacteriologists, 3 laboratory assistants, 8 laboratory helpers, one

stable foreman, 14 laborers, 2 janitors, and 6 clerks and stenographers.

At the Wassermann Laboratory located at the Harvard Medical School, there are the following personnel: one chief, one bacteriologist, one laboratory technician, one laboratory assistant, 5 laboratory helpers, and 3 clerks and stenographers.

4. Division of Communicable Diseases.
One medical director who serves as deputy commissioner; one assistant director, 7 district health officers, 3 epidemiologists, 8 clerks and stenographers.

The Diagnostic Laboratory which is under this division employs 4 bacteriologists, one laboratory assistant, one laboratory helper, one laborer, and 2 clerks.

The Bureau of Venereal Diseases which is also under this division employs one assistant director, one epidemiologist, one public health social hygiene supervisor, one public health education worker, and 2 clerks and stenographers.

5. Division of Food and Drugs.
One director, one chief of laboratory, 5 chemists and bacteriologists, 3 veterinary food inspectors, 7 food inspectors, 2 laboratory helpers, 2 laborers, and 7 clerks and stenographers.

6. Division of Child Hygiene.
One medical director, one epidemiologist, one child welfare physician, one public dental hygiene supervisor, 3 public health nutrition workers, 2 public health education workers, and 8 clerks and stenographers.

In the Bureau of Maternal and Child Hygiene in this division there are one child welfare physician, 5 public health nursing supervisors, and 6 clerks and stenographers.

7. Division of Sanitary Engineering.
One chief sanitary engineer, 15 engineers and engineering assistants, and 12 clerks and stenographers.

The Water and Sewage Laboratories which are now under this division employ one chief of laboratory, 10 chemists and bacteriologists, one laboratory assistant, one mechanical handyman, one laborer, one watchman, and 3 clerks and stenographers.

8. Division of Tuberculosis.
One medical director, one epidemiologist, one superintendent of sanatoria construction, one inspector of settlements and support claims, 2 social workers, one field nurse, and 9 clerks and stenographers.

The Traveling Tuberculosis Clinics which operate under this division employ 2 supervisors of tuberculosis clinics, 4 child welfare physicians, 4 field nurses, 3 public health nutrition workers, 2 X-ray clinic field agents, and 9 clerks and stenographers.

Special activities. — From time to time special activities of more or less temporary duration may become a part of the state health program which necessitate the employment of extra per-

sonnel or the shifting of personnel already employed in order that the special objective may be attained. The special activities depend on the particular needs of a locality. They include anti-typhoid, anti-diphtheria, and anti-tuberculosis campaigns, anti-mosquito, and anti-malaria projects, and campaigns against trachoma, poliomyelitis, maternal and infant mortality, heart disease, cancer, and other outstanding public health problems. These campaigns, initiated by the state department of health, are reflected in the activities of the local health departments, municipal or county. In this way, pressing public health problems are attacked and progress accomplished.

Progress in state health administration. — Although the public health service of many states until recent years has not been as progressive as that of the larger municipalities, there is little doubt that much progress has been made since 1915. Dr. E. L. Bishop, State Commissioner of Public Health for Tennessee, presents evidence to substantiate this fact in an article entitled, "Modern Trends in Public Health Administration" which appeared in the *American Journal of Public Health* for June, 1934. A survey of state health department activities in the United States was conducted by Dr. Charles V. Chapin for the American Medical Association in 1915, and his report was published in 1916. Using this report as a basis for comparison, it is possible to ascertain the progress made in state public health administration. Bishop maintains that between 1915 and 1930, state health service has given increased support to epidemiological work and to laboratory and sanitary engineering activity. In 1915, according to Chapin, only 14 states provided for epidemiological service and communicable disease control, while in 1930, the number had increased to 31. Again, in 1915, only 20 states had specific allotted funds for laboratory service, while in 1930, there were 42 states that maintained laboratories with specific funds allotted by the legislature for that purpose, and several others were maintaining laboratory service through the use of unallotted appropriations. Also in 1915, only 16 states offered sanitary engineering service, while in 1930, every state in the Union provided such service. Similarly, in the fields of maternity, infant and child hygiene, in public health education, and doubtless others, significant progress has been made in the service offered by the various state departments of health.

Federal health agencies. — When the Federal Constitution was created, it was understood that the powers not expressly delegated to the Federal Government were reserved for the individual states themselves. Accordingly, the Federal health agencies have no power or authority to enter a local community or state to improve the public health unless they are invited to do so, or unless the local or state public health situation is a matter of interstate concern. When bubonic plague was first discovered in San Francisco early in the present century and the local authorities denied the existence of the disease, the U.S. Public Health Service authoritatively threatened to quarantine the entire state of California unless the existence of plague were admitted and anti-plague measures adopted. The administration of the Pure Food and Drug Act, and the supervision of the sanitary quality of meats used in interstate commerce, both interstate problems, are functions of the U.S. Department of Agriculture. Federal health agencies are also responsible where the public health of the country as a whole is involved, as in keeping out cholera, typhus fever, smallpox, and other communicable diseases. The functions of the Federal health agencies are thus partly executive and partly advisory.

Although the U.S. Government, through its various Departments, is actively engaged in public health work, there is at present no Federal Department of Public Health. The U.S. Public Health Service approximates such a Department, but it is only a bureau in the Treasury Department. Attempts have been made in recent years to organize a joint Department of Health and Education with cabinet representation, but these efforts thus far have failed. Between 1878 and 1883, the United States did have a National Board of Health, but it was allowed to die a natural death through lack of financial support. This body was created by Congress in March, 1878, as a result of the cholera epidemics of 1872 and 1873, and more particularly because of the yellow fever epidemic that affected the southern states in 1878. Dr. Sternberg of the U.S. Army Medical Corps, one of the leading sanitarians of his time, estimated that this epidemic affected over 74,000 people and caused 16,000 deaths. The National Board of Health was created "to investigate the causes and means of prevention of contagious and infectious diseases, to indicate measures of national importance, and to be a distributing center of information relating to public health." Since 1883, the duties of the National Board of

Health have been performed and extended by the U.S. Public Health Service.

National health functions. — In the opinion of the American Public Health Association, formulated at its annual convention in October, 1933, and cited earlier in this chapter, the following are the desirable standard minimum functions of the Federal health agencies in the United States.

1. To meet all public health obligations under international treaties.
2. To control the spread of communicable diseases in international and interstate commerce.
3. To administer the medical and health services on national property and for Federal employees.
4. To conduct organized research for the discovery of the causes and means of control of preventable diseases.
5. To maintain the sanitary control of interstate traffic and carriers.
6. To maintain control over all foods and drugs shipped in interstate commerce.
7. To be of assistance in local health work at the request of states, cities, or counties.
8. To serve as a central agency for the collection, tabulation, and publication of the vital statistics of the various component political units.
9. To establish standards of control for the manufacture and sale of all biological products used in the treatment or prevention of disease.

The U.S. Public Health Service.—Since the U.S. Public Health Service is the most important single Federal health agency in the United States and is engaged in a great variety of public health activities, its organization and activities will receive prior consideration in this discussion. In 1931, it employed more than 5,000 men and women, most of them on a part-time basis, and its annual appropriation is approximately $11,000,000.

The U.S. Public Health Service had its origin in the U.S. Marine Hospital Service established by act of Congress on July 16, 1798. This act authorized the President to nominate and appoint medical officers to furnish care for sick and disabled seamen in all parts of the United States. It also provided that this care might be given either in hospitals maintained by the United States or in civilian institutions with which contracts had been negotiated. In order to finance this work, the act provided for a tax of 20 cents per month to be collected by the U.S. Customs officials of all seamen employed on American vessels and engaged in foreign

or coastwise trade. For this reason, the U.S. Public Health Service is a Bureau in the Federal Treasury Department today.

The first Federal marine hospital was built at Norfolk, Va., in 1800. In 1802, a hospital was built in Boston and others soon followed along the Atlantic coast, the Great Lakes, and along the Mississippi and Ohio rivers. Since the care of the sick and disabled seamen in these marine hospitals brought the medical officers in contact with diseases like cholera, yellow fever, and smallpox, imported from abroad, it was only natural that these men should be called on from time to time, especially during emergencies, to aid the local health authorities in the control of these and other imported diseases.

Gradually, Congress began to extend the functions of the Marine Hospital Service and to make it in reality a Federal health service. In 1878, it was given authority to impose quarantine and to prevent the introduction of disease into the United States from abroad. In 1890, authority was likewise granted to impose quarantine for the prevention of the spread of disease between the states, but this authority was first limited to cholera, yellow fever, smallpox, and plague. But in 1893, this authority was extended to include all communicable diseases. In 1902, the name of the U.S. Marine Hospital Service was changed to the U.S. Public Health and Marine Hospital Service, and in 1912, this name was changed simply to the U.S. Public Health Service. In 1901, Congress authorized the building of the Hygienic Laboratory for the investigation of communicable diseases, and in 1912, this authorization was broadened to include all the diseases of man and the conditions affecting their propagation and spread. In 1930, Congress increased the facilities for research into the diseases affecting man, provided for the acceptance of unconditional gifts and bequests for the study of the fundamental problems of disease, and changed the name of the Hygienic Laboratory to the National Institute of Health.

Functions of the U.S. Public Health Service. — The activities of the U.S. Public Health Service may be classified according to the following ten functions which it performs.

1. The protection of the United States from the introduction of disease from outside.
2. The medical examination and inspection of all arriving aliens and prospective immigrants.

3. The prevention of interstate spread of disease and the suppression of epidemics.
4. Coöperation with state and local health authorities in public health matters.
5. Investigation of the diseases of man.
6. The supervision and control of the manufacture of biological products such as viruses, vaccines, therapeutic serums, toxins, and antitoxins, and the testing of these products for purity and potency.
7. Public health education.
8. The maintenance of marine hospitals and relief stations for the care and treatment of certain beneficiaries prescribed by law.
9. The confinement and treatment of persons addicted to the use of habit-forming narcotic drugs who have committed offenses against the United States and of addicts who voluntarily submit themselves for treatment.
10. The providing of medical service in Federal prisons.

Administrative organization of the U.S. Public Health Service. — The U.S. Public Health Service is organized along military lines with officers holding commissions in grades comparable to those of the medical officers in the U.S. Army and Navy. The administrative head of the U.S. Public Health Service is the Surgeon-General. Below him in consecutive order are the assistant surgeon-generals, the medical directors, the senior surgeons, the passed assistant surgeons, and the assistant surgeons. There are eight divisions in the U.S. Public Health Service as follows:

1. Division of scientific research.
2. Division of marine hospitals and relief.
3. Division of foreign and insular quarantine.
4. Division of domestic quarantine.
5. Division of sanitary reports and statistics.
6. Division of venereal disease.
7. Division of mental hygiene.
8. Division of personnel and accounts.

Division of scientific research. — The investigations of the U.S. Public Health Service are conducted both in the laboratory and field and may be either clinical, epidemiological, microbiological, chemical, physical, sociological, statistical, and administrative in character. Any field of endeavor which is significant to the health and welfare of large portions of the population becomes a legitimate sphere of activity for research by the U.S. Public Health Service. The diseases under investigation in 1932 included cancer, cerebrospinal meningitis, diphtheria, encephalitis, heart disease, leprosy, malaria, nutritional diseases, plague, pneumonia, psittacosis,

relapsing fever, Rocky mountain spotted fever, smallpox, scarlet fever, tick paralysis, trachoma, tuberculosis, tularemia, typhus fever, and undulant fever. Also under investigation are such subjects as public health administrative practice, child hygiene, industrial hygiene and sanitation, atmospheric pollution, milk sanitation, morbidity in relation to cost and incidence, current mortality and morbidity statistics, rural health work, shellfish sanitation, stream pollution, and the regulation of the interstate traffic in biological products through inspections and special studies.

The National Institute of Health, which is a part of this Division, has four divisions of its own, namely, pathology and bacteriology, zoology, pharmacology, and chemistry.

Division of marine hospitals and relief.—The marine hospitals in the beginning were financed through a tax of 20 cents per month, later increased to 40 cents, deducted from the wages of each seaman and collected by the U.S. Collector of Customs. Subsequently this was replaced by a tonnage tax and finally by direct appropriations by the U.S. Treasury Department. In 1932, there were 25 marine hospitals distributed throughout the country, and more than 130 relief stations. These hospitals are open to disabled seamen, to the personnel of the Army, Navy, and Coast Guard, to patients of the U.S. Veterans' Bureau, to injured employees of the U.S. Government receiving care under the supervision of the Employees' Compensation Commission, to disabled foreign seamen, and at Ellis Island, New York City, to detained sick immigrants. A total of 343,054 persons applied for treatment and other medical services in 1932, and from 3,000 to 4,000 sailors are constantly being hospitalized. Dental, as well as medical treatment, is provided by full-time, commissioned dental officers at all marine hospitals. The marine hospital at Fort Stanton, New Mexico, is reserved for the treatment of the tuberculous, while at Carville, La., cases of leprosy are treated at what is known as the National Leper Home.

Division of foreign and insular quarantine. — This division has two major functions:

1. The prevention of the entrance of communicable diseases from foreign countries into the United States, a function which gives it jurisdiction over all ships and persons coming into American ports from abroad.
2. The medical examination of aliens applying for admission to the United States as immigrants.

During 1932, no case of quarantinable disease entered the United States from abroad. One case of smallpox and one case of typhus fever were detained at the domestic quarantine stations, and two cases of cholera occurring on a steamer bound for Manila, were detained at quarantine on arrival. At domestic ports, 13,256 vessels, 718,596 passengers, and 998,471 seamen were inspected on arrival by quarantine officers in 1932. At foreign ports, 2,173 vessels, 201,563 passengers and 160,761 seamen were inspected prior to embarking for the United States. In addition, 2,205 airplanes arrived at official airports of entry in the United States from foreign ports which required quarantine inspection. These planes carried 24,694 persons, and of this number 17,387 were medically examined.

Of the passengers who embarked at European ports in 1932, for entry into the United States, 26,564 were vaccinated and 10,190 were deloused. Clothing and baggage of these passengers, amounting to 24,489 pieces, were also disinfected. During the same period, 2,455 vessels were fumigated as a plague-preventive measure. Based on previous observations, it is estimated that fumigation of a cargo laden vessel will destroy about 80 per cent or more of the rats on board. At domestic ports, in 1932, 373,034 alien passengers and 897,788 alien seamen were examined by medical officers under the immigration laws, and at foreign ports 42,831 applicants for immigration visas were examined during 1931. Of the latter number, 9,079 were found to have mental or physical defects and of this group, 4,456 were refused visas.

Division of domestic quarantine. — This division was organized in 1910, and its functions may be summarized as follows:

1. Enforcement of the interstate quarantine regulations of the United States.
2. Development of state departments of health, especially divisions dealing with communicable disease control and sanitary engineering.
3. Control over water supplies used for drinking and culinary purposes on railroads, vessels, and other interstate carriers.
4. Sanitation of the national parks in coöperation with the National Park Service.
5. Measures for the control and prevention of trachoma.
6. Studies and demonstrations in rural sanitation.
7. Planning for and conducting the annual Conference of State and Territorial Health Officials.
8. Other contacts with state and territorial health officials relating to health administration.

Division of sanitary reports and statistics. — The work of this division has at least two phases — first, the collection of all information from the United States and all other parts of the world, having a bearing on the maintenance of the public health, and second, the compilation, analysis, and disemination of this information to such persons and organizations which can use it to the greatest advantage.

The information compiled by this division is secured from many sources, local, state, Federal, and international. Among the latter are the bulletins and other documents issued by the health section of the League of Nations and the International Hygiene Office in Paris. Every consul stationed abroad makes a routine weekly report to the U.S. Public Health Service of the prevalence of the more important communicable diseases in the area under his supervision. The information is obtained from the accredited health officials in each country and is forwarded on special forms. In case an outbreak of plague, cholera, yellow fever, or typhus fever occurs, the consul promptly cables the information. Such prompt information enables the officers of the U.S. Public Health Service to intercept any ships arriving in the United States from these ports and to take what measures of disinfection and segregation are necessary to prevent the entrance of these diseases into the United States.

Reports on the prevalence of disease in the United States are obtained weekly on special forms from the health officials in 570 cities having a population of 10,000 or more. These officials act as "collaborating epidemiologists" and are paid $1.00 per year. The reports on the current prevalence of disease both here and abroad are published weekly in *Public Health Reports* which is distributed to almost 10,000 persons and institutions.

Division of venereal diseases. — This division was created by act of Congress on July 9, 1918, its duties to be as follows:

1. To study and investigate the cause, treatment, and prevention of venereal diseases.
2. To cooperate with state departments of health for the prevention and control of such diseases within each state.
3. To control and prevent the spread of these diseases in interstate traffic.

Partly as a result of the stimulus provided by this division, practically every state now has public clinics for the treatment of gonorrhea and syphilis. It is estimated that more than 100,000

new patients are admitted annually to these clinics for treatment, and that the patients average 18 or more treatments before they cease attending the clinics. Approximately 50,000 patients annually remain under treatment in the public clinics until they are discharged either as arrested or cured.

As a means of preventing the interstate spread of the venereal diseases, a free clinic has been maintained by the U.S. Public Health Service since 1920, at Hot Springs, Arkansas, in coöperation with the National Park Service, for the treatment of indigent cases of venereal disease who come to Hot Springs for the free baths. This clinic attracts large numbers of individuals from many states, and operates most efficiently. Instruction in the diagnosis and treatment of the venereal diseases is also offered here to interested physicians. The Division of Venereal Diseases also conducts an extensive educational campaign throughout the country as well as important studies in the clinical, laboratory, and administrative phases of the venereal disease problem.

Division of mental hygiene. — In 1929, an act of Congress provided for the establishment of two institutions for the confinement and treatment of persons addicted to the use of habit-forming drugs. As a result a narcotics division was created in the U.S. Public Health Service charged by law not only with the administration of two narcotic farms, but also with the duty of studying the nature of drug addiction and the best methods of treating and rehabilitating persons addicted to the use of habit-forming drugs. In addition, this division was required to disseminate information on the best methods of treatment and research and to coöperate with the state and local authorities in developing facilities for the care and treatment of narcotic addicts. It is estimated that there are at least 110,000 drug addicts in the United States and that the number does not exceed 200,000.

Since the majority of individuals now addicted to the use of habit-forming narcotic drugs are mentally ill, the approach to the problems of treatment, segregation, care, and rehabilitation is evidently through the field of mental hygiene. Recognizing this, a bill was introduced into Congress and enacted on June 14, 1930, which changed the name of the Narcotics Division to the Division of Mental Hygiene and materially enlarged its powers and functions. Not only does this new division have charge of the operation of the two narcotic farms, but it was also requested to make studies

and investigations of the abusive use of narcotic drugs, the quantity necessary to supply the normal and emergency medical and scientific requirements of the United States and to investigate the causes, prevalence, and means for the prevention and treatment of mental and nervous diseases. In this way, the care and treatment of the drug addict became only a part of the much larger and more important problem of mental hygiene.

Division of personnel and accounts. — This important division is the administrative center of the U.S. Public Health Service. This agency handles all matters affecting the movements of personnel and maintains complete records of appointments, promotions, leaves of absence, and discipline. In addition, this division prepares the budget for all branches of the Service, apportions the appropriation made available by Congress, maintains an elaborate system of cost accounting, and acts as the property office through which all supplies are purchased, distributed, and accounted for.

Other Federal health agencies. — The collection, tabulation, and analysis of the vital statistics of the United States, one of the basic elements in any intelligent public health program, is performed by the Bureau of Census in the U.S. Department of Commerce. This Bureau publishes annually an analysis of the births, deaths, and stillbirths in the various Registration Areas which it maintains and helped to create. In addition, it conducts a census of the total population every ten years and publishes valuable reports on the resulting compilations and analyses. From time to time, other valuable reports dealing with vital statistics and based on special studies are issued by this Bureau.

The Bureau of Mines, also in the U.S. Department of Commerce, conducts investigations aimed to enhance the safety of mines against accidents, against carbon monoxide, and other hazards to life and limb in the mines.

The Children's Bureau which has made excellent studies on infant and maternal mortality and has published popular pamphlets on *Pre-natal Care, Infant Hygiene, The Care of the Pre-school Child,* and others dealing with *Child Management* and *Guiding the Adolescent,* is a part of the U.S. Department of Labor. The Children's Bureau also administered the Sheppard-Towner Maternity and Infancy Act and has conducted interesting studies and demonstrations on rickets.

In the U.S. Department of Labor there are also found the Wom-

en's Bureau which is concerned with the health and welfare of women in industry; the Bureau of Labor Statistics which compiles labor statistics and conducts studies on occupational diseases; and the Bureau of Immigration which is charged with the administrative responsibility for the medical examination of all aliens entering the United States. The examinations, however, are performed by the medical officers of the U.S. Public Health Service.

Various Bureaus are also found in the U.S. Department of Agriculture which are actively engaged in certain phases of public health work. The Bureau of Animal Industry supervises the slaughtering and shipment of all animal foods used in interstate commerce. By means of ante-mortem and post-mortem examinations, and by prescribing the essential sanitary requirements under which packing plants may operate, the use of meat from healthy animals and its sanitary handling is assured. The important Pure Food and Drugs Act, through which the sanitary quality of all foods shipped in interstate commerce and their freedom from adulteration are safeguarded, is administered through the Food and Drug Administration. Other bureaus in this Department which conduct work of public health significance are the Bureau of Dairying, which is concerned with the economic and sanitary problems of the dairy industry; the Bureau of Home Economics, with the problems of dietetics and nutrition; the Bureau of Entomology, with the effects of insects on the health and welfare of man and domestic animals; and the Bureau of Public Roads, in the design and use of sanitary conveniences on the farm.

The U.S. Department of the Interior contains the Bureau of Education, the Bureau of Indian Affairs, and the Geological Survey, all of which are interested in special phases of public health work. The Bureau of Education has made investigations and published excellent reports on school hygiene and physical education, and has charge of the health of the natives of Alaska. The Bureau of Indian Affairs concerns itself with the relief of distress and the prevention of disease among Indians, while the Geological Survey has as one of its functions the investigation of water supplies.

Non-official national health agencies. — Of vast importance in the organization and conduct of the national public health program in the United States are the various non-official, national health agencies and the large, philanthropic foundations which are interested in promoting the public health. They carry on extensive

programs in health education, conduct public health demonstrations, aid in the conduct of important laboratory, statistical, and field researches, establish clinics, finance the education of properly qualified men and women in the various phases of public health, and aid in a variety of other ways. Often they pave the way for the adoption of progressive health measures in city, county, state, or nation, carrying on such activities until the government is able officially to take over the work. Without the stimulus and aid of the voluntary health agencies in the United States public health progress would have been slow and its scope greatly restricted.

While it is impossible here to describe in detail the organization and activities of each of the numerous non-official, national health agencies, a brief statement concerning each of the more important agencies is recorded here in order to satisfy the requirements of the subject under consideration. Some of the philanthropic foundations will be given prior consideration.

International Health Division of the Rockefeller Foundation. — Of far reaching importance to the public health of the world have been the activities of the Rockefeller Foundation through its International Health Division. Starting as the Rockefeller Sanitary Commission for the Eradication of Hookworm Disease on October 26, 1909, it gradually enlarged its activities to include the control of such important diseases as malaria, yellow fever, tuberculosis, and the common cold. It has established schools of hygiene and public health in Baltimore, Boston, Toronto, London, Rome, and other places, and has financed the education of selected men and women in almost every part of the world. It has aided liberally in the conduct of laboratory, field, and statistical research of important public health problems, and has stimulated progress in public health administration under rural and urban conditions in the United States and in many other countries throughout the world. It has given liberal aid for the education of suitable personnel in the fields of medicine, public health nursing, public health engineering, and health education as well as in the general field of public health. Through the Rockefeller Institute for Medical Research and the Rockefeller Institute for Animal Research, it has made notable contributions to our knowledge concerning the etiology, modes of transmission, and the prevention and control of many diseases. According to the *Report of the Rockefeller Foundation for 1932* (page 30) "the aim of the public health program is not

merely to gain new knowledge of a limited number of diseases and public health problems, but by concrete demonstrations in the control of these maladies, to fix attention upon problems of public health, to educate the public, and to induce governments to increased attention to the fundamental health needs of mankind."

The Commonwealth Fund. — The Commonwealth Fund of New York was organized in 1918 and has been interested in providing educational opportunities in the United States for selected young men and women from the British Empire, and in promoting the health of people in the United States who live under rural conditions. It has financed special researches in mental hygiene, pneumonia, rheumatic heart disease, normal kidney function, dental decay, infectious abortion in cattle, trachoma, the value of prenatal care in the prevention of stillbirths, maternal mortality and neonatal deaths, public health nursing, and a variety of other public health and medical subjects. It is well known for the four child health demonstrations mentioned in the chapter on child health. Its primary interest in public health work, however, is to provide suitable hospital facilities, well-trained physicians and nurses, and a first class health department for rural areas. To this end, it finances the education of selected personnel, erects and equips modern hospitals, aids in the organization of adjoining rural communities into health districts which provide progressive and effective public health service, promotes the cooperation between the practising physician and the public health authorities, and by means of careful, scientific appraisals determines those phases of its program which require greater or less emphasis.

The Milbank Memorial Fund. — This organization has conducted important public health demonstrations in Cattaraugus County, N.Y., in Syracuse, N.Y., and in the Bellevue-Yorkville District of New York City. It has also aided in important studies in ventilation and in the studies performed by the Committee on the Costs of Medical Care.

Other philanthropic agencies interested in public health. — Among the other philanthropic agencies interested in promoting the public health on a state-wide or nation-wide basis are the Russell Sage Foundation, the Julius Rosenwald Fund, the Cousens Child Welfare Fund of Michigan, and the W. K. Kellogg Foundation. The Metropolitan Life Insurance Company, though not a philanthropic foundation, is included in this group because of the

financial and professional aid it has given to numerous public health projects. It financed the tuberculosis demonstration of Framingham, Mass., and aided in studies dealing with influenza, health education, and other important public health subjects.

National health organizations. — In addition to the various philanthropic agencies or foundations that are interested in promoting the public health, there are numerous national organizations that are also active in public health work. Some of these are professional health societies, while others are essentially educational and promotional in character. The former are supported largely by membership dues, while the latter enjoy moderate endowments and raise funds by membership campaigns, the sale of seals, and other devices. Among the important national health agencies which play a prominent rôle in promoting the public health are the following:

American Public Health Association. — This organization was founded in 1871 and is the recognized association of professional and lay public health workers in North America. It is composed of ten sections, descriptive of the chief interests of its members. The sections are as follows: Health Officers; Laboratory; Vital Statistics; Public Health Engineering; Industrial Hygiene; Food and Nutrition; Child Hygiene; Public Health Education; Public Health Nursing, Epidemiology. The Association holds an annual convention and publishes from time to time revised editions of standard methods of water, sewage, milk, air, and shellfish analysis as well as other aids in public health work such as the *City and Rural Health Appraisal Forms.* It also publishes monthly the *American Journal of Public Health.* Through its various committees it acts as a constant stimulus to more progressive public health work in North America.

American Child Health Association. — This organization, which absorbed the American Association for the Study and Prevention of Infant Mortality and the Child Hygiene Association of America, has done notable work. It organized and conducted the Health Survey of 86 Cities which was largely responsible for the evolution of the *City Health Appraisal Form.* It organized and conducted the School Health Survey which exposed the lack of scientific validity of the height-weight-age tables as indices of nutrition and substituted for them the ACH measurements. The American Child Health Association also prepares annually an

early estimate of the infant mortality rates in the towns and cities of the United States. Excellent milk surveys have been made in various parts of the country as a means of stimulating the production of clean and safe milk. Classes have been held for training colored midwives in the south and some of the best work in health education in the United States has been performed by this organization.

American Red Cross. — The work of this organization during emergencies such as flood, famine, earthquake, and war, is well known. It stands ready to offer medical and nursing relief during emergencies, to provide sanitary protection, and to supply food, clothing, and shelter. It maintains branch organizations in every city, town, and hamlet throughout the United States. During the World War it established health centers, conducted nutrition classes, classes in home hygiene and the care of the sick, and classes in first aid and life saving. It has also provided public health nursing service and has cooperated in supporting and promoting the community health program.

American Medical Association. — This association is the professional organization of physicians in the United States. It has a section on Preventive Medicine and publishes the popular health journal *Hygeia*. In the past it exposed the fraudulent nature of certain patent medicines and nostrums, and the fraudulent claims of all sorts of medical quacks. Through its Committee on Foods, it has had a wholesome effect on the quality and claims of many foods and food products offered for sale in the United States. Through its Council on Pharmacy and Chemistry, it has exerted a similar beneficial effect on the quality, potency, and efficacy of certain drugs and chemical and biological products offered for sale as therapeutic or prophylactic agents. It conducts a radio program of health education, publishes its famous weekly *Journal*, and from time to time issues various publications on disease prevention and other aspects of public health.

National Tuberculosis Association. — This organization was founded in 1904 by a group of distinguished professional and lay men and women. While its chief interest has been to combat tuberculosis, it has exerted an exceedingly beneficial effect on the general health program throughout the United States. It has branch organizations in every state and in most of the cities and towns within each state. It conducts annually the sale of Christmas

seals from which it derives much of its financial support. It publishes monthly the *Journal of Outdoor Life*. It has fostered and supported research in tuberculosis of a high order, has been a leader in the field of health education, has conducted campaigns for early diagnosis and for the establishment of clinics, sanatoria, and preventoria, and has developed standards for a well-rounded tuberculosis program. It has also made valuable statistical and field studies and has published pamphlets from time to time dealing with special phases of tuberculosis and public health work.

Other national agencies. — Among the other national agencies that should be included in this list are the American Society for the Control of Cancer, the American Heart Association, the American Social Hygiene Association, the National Committee for Mental Hygiene, and the National Organization for Public Health Nursing. These organizations publish their separate journals, engage in research and educational activities, and in various other ways aid the official and voluntary health programs which aim at the control of the specific disease or condition that brought them into being.

Vital statistics. — One of the fundamental requirements for an intelligent, scientific analysis of a public health situation is a set of complete and accurate vital statistics. To the sanitarian, they serve as the chart and compass in the great field of public health endeavor. Public health administration, epidemiology, sanitation, child hygiene, adult hygiene, and the general community welfare are dependent on analyses of vital statistics for intelligent guidance and action.

Definition. — The term "vital statistics" has been defined as "the numerical registration and tabulation of data pertaining to population, marriages, divorces, births, diseases, and deaths coupled with analyses of the resulting numerical phenomena." It has also been defined as "the statistics relating to the life histories of communities or nations." It represents the life bookkeeping of a community. An intelligent analysis of the vital statistics of a community is invariably of great potential value, and if properly presented cannot fail to enlist the interest of all thoughtful people.

Methods of collection. — Vital statistics are collected in two ways, by enumeration and by registration or reporting. Enumeration is employed to determine the population of a place and its

composition by age, sex, nativity, color, conjugal condition, and other factors. It is the method used by the U.S. Census Bureau every ten years when the census of the United States is taken. The data obtained are carefully tabulated and analyzed, and in that form, they represent a reservoir of information of great value to the national welfare, to business and industrial interests, to students of social problems, and to public health officials. They tell the man-power of the nation, the proportion of each sex in the total population, the composition of the population by color and nativity, the trend of these vital factors, the population available for taxation, the size and economic status of each family, the occupations of those employed, the amount of illiteracy, the conjugal state of the population, the distribution according to age, the concentration and congestion of the population, and numerous other interesting and important items. In addition, the census data on population form the basis for the computation of the birth rate, death rate, specific death rates, marriage rates, and other significant statistical data.

The second method of collecting vital statistics, *i.e.*, by registration and reporting, is used for the collection of data pertaining to births, deaths, diseases dangerous to the public health, marriages, and divorces. In the case of births, prompt reporting is encouraged by legal requirements, and by paying the attending physician $0.25 for every birth he reports. In the case of deaths, reporting is made reasonably complete by requiring the attending physician to file a death certificate, properly filled out with the health officer before a burial permit is issued for the disposal of the body. Where death has occurred suddenly, or through violence, or by accident, the medical examiner or coroner as he is sometimes called, fills out the death certificate before the burial permit is issued. Marriages and divorces are also carefully registered, and the resulting data are usually complete. In the case of reportable diseases the condition is not so favorable, for very few diseases are reported completely in any community, and in some the reporting is obviously incomplete.

Value of vital statistics. — While one or more aspects of the vital statistics of a community are used constantly by various professional, business, and civic groups, their use by public health officials only will receive consideration here. Among the public health personnel especially interested in vital statistics are the

health officer, the epidemiologist, and the public health engineer. The vital statistician or the statistical expert also uses vital statistics but his researches and analyses are utilized primarily for epidemiological, administrative, or educational purposes. Other members of the health department personnel who may and often do use vital statistics advantageously are the child welfare physicians, the adult hygiene specialists, and the public health nurses. Some of the specific uses of vital statistics in a health department may be enumerated as follows:

Some Uses of Vital Statistics

A. *By the health officer.*
1. To determine the efficiency of the public health campaign.
2. To determine the relative values that should be assigned to the different health activities.
3. To determine the relative amount of money that should be spent on each activity.
4. To obtain and plead for adequate appropriations for public health purposes.
5. For purposes of publicity and education.
6. For epidemiological analyses and studies.
7. To devise a public health program for a community based on an intelligent and scientific understanding of the needs of the local situation.

B. *By the epidemiologist.*
1. To obtain knowledge concerning the exact location of all preventable diseases in the community.
2. To detect epidemics in their incipiency.
3. To predict the occurrence of epidemics and to plan for their control by studying their periodicity.
4. To ascertain the normal prevalence of each reportable disease in the community.
5. To ascertain the distribution of disease by age, sex, nativity, ward, color, season of occurrence, religious affiliation of the afflicted, occupation, conjugal condition, social and recreational activities of the sick before illness occurred, and various other factors, in making an epidemiological study of a particular disease.
6. For the preparation of spot maps showing the prevalence and location of certain communicable diseases and deaths in the community.
7. As a basis for ascertaining the probable mode of spread of a given disease.
8. For determining the most susceptible and fatal age groups in a community with relation to specific diseases, in order that a more effective campaign of prevention and control may be inaugurated.

C. *By the public health engineer.*
1. For estimating future populations and their probable composition in order to determine
   (a) The size of water mains, sewers, and units employed for collecting municipal refuse.
   (b) The size of the water purification plant, sewage treatment facilities, and refuse disposal works.
2. For studying the epidemiology of typhoid fever, malaria, yellow fever, hookworm, typhus fever, and other diseases of particular interest to the public health engineer.
3. For planning parks, playground and recreational facilities.
4. For the formulation and adoption and substance of zoning regulations.
5. For the alleviation or elimination of congestion by studying existing conditions of overcrowding and planning for the more adequate and effective distribution of the population. This necessitates studying the problem of daily population flow in relation to existing and proposed housing facilities, transportation facilities, highways, bridges, tunnels, and other devices for ready access to and from the areas under consideration.

U.S. Census registration areas. — If vital statistics are to achieve their maximum value, they must be complete and accurate. While the accuracy of the cause of death recorded on the death certificate depends on the diagnostic ability of the attending physician and may not always be correct, the reporting of all deaths that occur in a community should be easy of attainment. And yet it was not until 1900, that the United States began to register births and deaths. A few states and some cities had good systems of registration at that time, but there were no birth or death statistics for the country as a whole. In 1850, the Federal Government published the first mortality statistics for the entire United States. These were for the single year, 1850, and were based on the information obtained by the census enumerators during the census of 1850. This practice was continued at each census enumeration through 1900.

But in 1880, a registration area for deaths was established by the U.S. Census Commission consisting of Massachusetts, New Jersey, and the District of Columbia, from which transcripts of death certificates were received. This was repeated in 1890 and 1900 with the addition of other states, mostly from New England, to the registration area. In 1901, a permanent Bureau of Census was established as part of the Federal governmental machinery, and action was soon begun to establish a U.S. Registration Area

for deaths. In order to be admitted to this area, the city or state applying had to adopt a standard and uniform system of registration and the model or standard death certificate. Furthermore, at least 90 per cent of the deaths occurring in the city or state, as determined by actual test, had to be reported. Admission to the registration area for deaths also required the enactment of a state law prohibiting the issuing of a permit for the burial, cremation, transportation, or other method of disposal for a corpse until the standard death certificate, properly and completely filled out, and signed by the attending physician, had been filed with the local registrar. The local registrar is required to file these certificates once a month with the state registrar who examines them for completeness and accuracy. The Federal Government then purchases transcripts of these certificates which are compiled in tabular form and analyzed, and the results are published annually as a report on the Mortality Statistics for the U.S. Registration Area.

The original registration states in the U.S. Mortality Registration Area in 1900 included the New England states, New York, New Jersey, Michigan, and Indiana. At first, this area grew slowly, later, with increasing rapidity, and in 1933 with the admission of Texas, the entire country was included for the first time.

Similarly, a U.S. Birth Registration Area was organized by the U.S. Census Bureau for the first time in 1915. Admission to this area was based on the adoption of the standard birth certificate, the handling of birth returns by local and state registrars in a manner similar to that employed for death returns, and the reporting of at least 90 per cent of the births occurring. The original Birth Registration Area included the New England states, New York, Pennsylvania, Michigan, Minnesota, and the District of Columbia. By 1930, every state in the Union, excepting South Dakota and Texas, had been admitted, and by 1934, the Birth Registration Area was complete. The U.S. Census Bureau also publishes an annual report on Birth Statistics which includes the tabulation and analysis of the statistics pertaining to births, stillbirths, and infant deaths occurring in the U.S. Birth Registration Area.

Proposed U.S. Morbidity Registration Area. — Communicable and occupational diseases in a community are reportable to the local health officer and not to the local registrar of vital statistics

if the latter is not a member of the health department as is frequently the case. Accordingly, where the state registrar of vital statistics is not identified with the state department of health, he does not receive the data on the local prevalence of reportable diseases. Instead, this information is transmitted to the state department of health where it is employed for epidemiological purposes. Similarly, the U.S. Census Bureau does not obtain or analyze the morbidity data for the various states. Instead, the collections and analyses are made by the U.S. Public Health Service.

In 1929, the U.S. Public Health Service proposed a plan to establish a U.S. Morbidity Registration Area on July 1, 1930. The area was to include those states, cities, towns, counties, townships, or other civil divisions which could meet the requirements for reporting disease. Only six diseases — diphtheria, poliomyelitis, scarlet fever, smallpox, typhoid fever, and tuberculosis — were to be used as the criterion for adequate reporting, the requirement being that at least 75 per cent of all the clinically recognized cases of these diseases occurring in a given area should be reported.

In order to ascertain whether these diseases were being reported with this degree of completeness, surveys were made in 1930 by state and local health officers at the request of the U.S. Public Service in 5 states, 35 cities, and 101 counties. The results showed that tuberculosis was poorly reported in all states and that the reporting of communicable diseases in general was below expectations.

Another plan was therefore suggested to stimulate the more adequate reporting of disease. In 1916, Dr. John S. Fulton, Commissioner of Public Health for Maryland, proposed the establishment of a morbidity registration area based on case fatality rates, *i.e.*, the number of deaths from a given disease per 100 cases of the disease. The same proposal was made by the New York State Department of Health in 1930. Accordingly, the U.S. Public Health Service now decided to use this plan to establish a morbidity registration area and to pay to the state department of public health of each state admitted, the sum of five cents for each transcript of an original reported case of disease. In this way, provision would be made for the necessary clerical aid.

Only five diseases are to be considered under this plan — diph-

theria, measles, scarlet fever, typhoid fever, and whooping cough. The average number of reported cases per death for each of these diseases occurring during the past three years in the U.S. Mortality Registration Area was to be used as the standard for satisfactory reporting. The states that could meet this standard would be included in the morbidity registration area. For the years 1927, 1928, and 1929, the average number of cases per death for diphtheria was 11; for measles, 106; for scarlet fever, 78; for typhoid fever, 5; and for whooping cough, 26. But even on this lenient basis, only 24 states rated above standard. As yet, the proposed morbidity registration area has not officially been established.

Organization for handling vital statistics. — Brief reference has been made already to the difference in method employed by various states in handling their vital statistics. In Massachusetts, for example, the birth, death, and marriage records are handled by the city clerk in each community, even though the death certificate must first be presented at the health department in order to obtain a permit for the final disposal of the body. Each city clerk in turn is responsible to the State Registrar of Vital Statistics who is under the Secretary of the Commonwealth. In the case of disease however, reports are made in each community to the local health department and from there to the state department of health. In other states, like New York, New Jersey, and Pennsylvania, the local health officer or his delegate is the registrar of the vital statistics in the community and he reports to the state registrar of vital statistics who is affiliated with the state department of health.

Population data. — The statistics on population represent the basic data for computing many of the rates used in analyzing the vital statistics of a community. A thorough knowledge of the composition of the population by age, sex, nativity, color, racial stock, occupation, economic status, etc., is exceedingly helpful in the proper interpretation of death rates, birth rates, specific death rates, and other statistical computations. Since the total population is used as the base for computing annual death rates, birth rates, etc., it is necessary to know or to estimate the number of people in a community each year. The actual enumeration of the population in the United States has been performed every ten years since 1790. From then until 1900, the work was performed by special U.S. Census Commissions appointed to last

only until the enumeration, tabulation, and analysis had been completed. In 1901, a permanent U.S. Census Bureau was created in the U.S. Department of the Interior. In 1903, it was transferred to the Department of Commerce and Labor, but later when this Department was divided, it was placed in the Department of Commerce, where it is today.

Some states, like Massachusetts and New York, have also conducted decennial censuses, usually in the years ending in 5. In such states, therefore, an enumeration of the population was made every five years. In recent years, however, the state censuses have been greatly curtailed in scope and thoroughness, and in some instances have been abandoned altogether. Furthermore, only the U.S. Census data are recognized legally. In view of the importance of accurate population data for many purposes, the suggestion has been made that the U.S. Census Bureau should conduct a census of the population every five years, but as yet no action toward this end has been taken.

Methods of estimating future populations. — Since the actual enumeration of the population takes place only once in ten years, and the population of every civil unit must be estimated each year, it is necessary to obtain as satisfactory an estimate as possible. Water purification plants, sewage treatment works, and other public utilities are designed to function for at least twenty-five years or more, so that it is necessary in such cases to estimate accurately the probable population to be served that far in advance. Sometimes, it is necessary to make estimates over longer periods of time. The methods commonly used for estimating future populations may be classified as follows:

1. Method of natural increase.
2. Arithmetic method.
3. Geometric method.
4. Graphical methods.
5. Other or miscellaneous methods.

Estimating the population by determining the natural increase is applicable usually only to national units and not to the cities and states that compose them. Knowing the population of the United States for 1930, for example, as a result of the census enumeration, it is possible to determine the population for 1931, 1932, 1933, or any other post-censal year, by ascertaining the excess of births over deaths and the difference between immigra-

tion and emigration. Where this is done the population estimate is made by determining the natural increase.

The arithmetic method of estimating population is the one commonly employed by public health statisticians. It is the method of "simple interest." Since the population is constantly changing because of births, deaths, immigration, and emigration, an arbitrary date must be selected for all official estimates of the population. For public health purposes, and for other purposes as well, the population of July 1 is considered official. This must be taken into consideration in making arithmetical and geometric estimates of the population, for the Census data on which these estimates are based are not recorded for July 1. Furthermore, the Census enumerations, though recorded for the years ending in zero, have frequently been made on different days. From 1790 to 1820, they were made on the first Monday in August, a variable date. From 1830 to 1900, they were made on June 1, a constant date. In 1910, however, the census was taken on April 15th; in 1920, on January 1; and in 1930, on April 1. In recent years, therefore, the interval between the census enumerations was not exactly ten years, but either nine and a large fraction years or ten and a small fraction years. This fact must be taken into consideration in computing the average annual increase in population between two census enumerations. Having done that and having then determined the average annual increase in population between the last two census enumerations, the population for July 1 for any post-censal year may be readily computed. It is assumed that the city or state under consideration will increase numerically during each post-censal year to the same extent it did during each of the intercensal year.

Estimating future populations by the geometric method is the method of "compound interest." In the arithmetic method the annual numerical increase in population is constant. In the geometric method, the annual numerical increase in population is not constant, but the annual *rate* of increase is constant. For post-censal years, estimates obtained by the geometric method are higher than those obtained by the arithmetic method. The reverse is true for intercensal estimates.

For estimating population by the geometric method the formula

$$P_n = P_c(1 + r)^n$$

is employed. In this formula

$$
\begin{aligned}
P_n &= \text{population at the later date} \\
P_c &= \text{population at the earlier date} \\
r &= \text{rate of increase in population} \\
n &= \text{number of years between } P_n \text{ and } P_c.
\end{aligned}
$$

To estimate the population for a post-censal year by this method P_n first represents the population of the last census, P_c the population of the preceding census and n the number of years between the two census enumerations. The formula can then be solved for r — the annual rate of increase — since all the other factors are known. In order to solve for r, the formula is first resolved as follows.

$$
\begin{aligned}
P_n &= P_c(1 + r)^n \\
\frac{P_n}{P_c} &= (1 + r)^n \\
\log P_n - \log P_c &= n \log (1 + r) \\
\frac{\log P_n - \log P_c}{n} &= \log (1 + r).
\end{aligned}
$$

Having determined the value of r or more simply $\log (1 + r)$, the formula is used again to get the desired post-censal estimate of the population. Now P_n is unknown for it is the population of the post-censal year; P_c represents the population of the last census; n is the number of years between the date of the last census and July 1 of the post-censal year for which the estimate is being made; and $\log (1 + r)$ has already been determined. Since every factor except P_n is known, it is possible to solve the equation for that item.

Among the graphical methods employed for estimating future populations, two are commonly used. In the first, the growth of the city or state under consideration is plotted, using the U.S. Census data for this purpose, after which the graph is extended to the year desired but only after allowance has been made for the probable future growth. If years are represented along the X axis and population along the Y axis, a line drawn parallel to the X axis from the point where the curve intersects the year under consideration will enable the analyst to determine the probable population at that time. This method is employed for estimating populations 50 to 75 years hence. For city, state, and national planning, knowledge of the probable population so far in the future is often required.

In the second graphical method frequently employed the growth curves of various cities now larger than the city under consideration are studied simultaneously. The cities used for comparison should be in the same geographical area, they should have similar industries, and the composition of the population by age, color, nativity, etc., should be similar. Other factors which may also influence community growth should be similar. Having plotted the growth curves of these cities, they are allowed to intersect at the point representing the present population of the city under consideration, and the assumption is now made that this city will grow at a rate midway between the slowest and most rapid growth enjoyed by the cities under comparison. By extending this curve 30 or 40 years beyond the present population, it is possible to determine from the chart the probable population of the city at that time. This method is valuable for estimating probable future populations where the construction of public works is involved.

There are also many local indices for obtaining a rough approximations of the population during any post-censal year. Among these are the number of school children, the number of registered voters, the number of new building permits, the amount of bank clearings, and the number of passengers carried on public vehicles such as trolleys and buses, etc. If a ratio between population and each index can be established for the last census year, then the population for any post-censal year can be determined by utilizing this ratio and its corresponding index for the year under consideration.

Computation of rates used in public health statistics. — The mere compilation of births and deaths is of little value; but if they are utilized to determine birth rates and death rates, their value is greatly enhanced. The following rates are frequently employed by public health statisticians and it is therefore important to know how they are computed and what they mean.

The *general death rate*, sometimes called the crude death rate or gross death rate, is defined as the number of deaths occurring in a community during a given year per 1,000 of the midyear population for that year.

The *birth rate* is the number of live births occurring in a community per year per 1,000 of the midyear population for that year.

The *marriage rate* is the number of persons married in a com-

munity per year per 1,000 of the midyear population for that year The *wedding rate* is one-half the marriage rate.

The *divorce rate* is the number of persons divorced in a community per year per 1,000 of the midyear population for that year.

Fatality rate is the number of deaths from a given disease per 100 cases of that disease. The interval of time is constant for the cases and deaths under consideration.

Stillbirth rate is defined as the number of stillbirths occurring in a community during a given year per 100 live births occurring in the same community during the same interval of time.

Maternal mortality rate is defined as the number of maternal deaths asssociated with childbirth occurring in a community during a given year per 1,000 live births occurring in the same community during the same period of time.

Infant mortality rate is defined as the number of infant deaths occurring in a community in one calendar year per 1,000 live births occurring in the same community during the same interval of time. The *neonatal infant mortality rate* is computed in the same way, except that only the deaths of infants under one month are considered.

Specific death rate for a given cause is defined as the number of deaths from that cause occurring in a community during a given year per 100,000 of the midyear population of the same community for the same year. Where the specific death rate computed on this basis is less than one, the computation should be based on 1,000,000 of the population. The base used should be indicated clearly whenever specific death rates are employed. Where specific rates by age are computed, and not by cause and age combined, the base is usually 1,000 of the midyear population.

Standardized death rate or death rate adjusted to the standard million. This rate is highly valuable for it takes into consideration the age distribution of the population in the city under consideration in the computation of the death rate. It is obvious that a community containing an excessive proportion of individuals under 5 or over 70 will show a higher death rate than one which has a normal or less than normal distribution of the population in the early and late age groups, and a greater proportion of young, vigorous adults. A comparison of the general death rates of two communities is therefore of little value. The standardized death rate takes age distribution into consideration by utilizing the age

distribution of the population of England and Wales for 1901 for comparison. This population is known as the "standard million" and was selected because it was not affected by immigration or emigration and was considered to have a normal age distribution.

In order to standardize a death rate, the midyear population for the year and community under consideration is first divided into age groups to correspond with those of the "standard million." The deaths from all causes occurring in the same community during the same year are now divided into corresponding age groups. The specific death rate per 1,000 population for each age group is then determined. Each of these rates is then multiplied by the proportion of the "standard million" in the corresponding age group, the resulting figures are added together, and the result is the standardized death rate.

This rate may approximate or equal the general death rate or it may be very different, the variation depending on the extent to which the population of the city under consideration approximates a normal or standard age distribution.

Analysis of death rates. — The limitations of the general death rate as a means of determining the healthfulness of a community have been indicated already, for it does not take into consideration such important factors as age distribution, cause of death, geography, sex, occupation, color, nativity and racial origin, marital condition, education, and economic status. If general death rates are to have any significance, they must be analyzed according to these factors. This means the computation of specific death rates for each factor and for as many of them together as the available data will permit. Such an analysis will bring out the most important causes of death, and the age groups, sex, nativity, color, ward, occupation, etc., most affected. If death rates are analyzed in this way, much can be learned that will be of value in formulating an effective program of prevention and control. Similar analyses should be made for birth rates and infant mortality rates, and other factors that are specifically applicable should be included.

The International List of Causes of Death. — If statistics are to have value for purposes of study the terms employed, such as the causes of death, should have the same meaning wherever they are used. Without uniformity in the interpretation of all statistical

units, comparative studies of intrinsic value cannot be made. Although a proper and clear classification of the causes of death would seem to be a simple undertaking, it was not until 1893 that the International Classification of Diseases and Causes of Death was introduced. In that year, the International Statistical Institute met in Chicago and after making some changes in the proposed classification, adopted the list. The Institute also provided for the decennial revision of the causes of death by an International Commission. Such revisions have been made in Paris in 1900, 1909, 1920, and 1929. We are indebted primarily to Dr. Jacques Bertillon of France for initiating this desirable system of classification.

The present *International List of Causes of Death* represents the fourth revision, and the causes of death are distributed into eighteen classes. These were listed in chapter 1. Each cause of death is identified by a number, partly for convenience but largely for purposes of subsequent analysis by the use of punch cards and sorting machines. Exactly 200 causes of death are listed exclusive of minor subdivisions.

Manual of Joint Causes of Death. — On the death certificates now in use, the physician is required to record the principal and important contributory causes of death. When the public health statistician subsequently examines each death certificate, he must decide whether the principal cause of death as listed is really the principal cause or whether one of the contributory causes is the principal cause. As an aid in making such decisions and for the sake of uniformity, the U.S. Census Bureau prepared the *Manual of Joint Causes of Death* in which each cause as listed in the International List of Causes of Death is classified according to priority against every other cause of death to determine its relative priority. By referring to this *Manual* the public health statistician can ascertain promptly whether the principal cause of death as recorded on the death certificate should have priority over the recorded contributory cause, or vice versa. In general, an acute condition such as an "infectious and parasitic disease" has priority as cause of death over a chronic condition even of long duration. It must be apparent that in analyses of public health statistics where so many varied interpretations may be employed uniformity of practice and understanding is absolutely essential if the results are to have significance.

Public health surveys. — Just as it is impossible for an individual, apparently well, to detect the onset of insidious disease without recourse to a periodic expert medical examination, so it is impossible for public health administrative practice in any community to maintain the highest level of efficiency and effectiveness without recourse to a periodic public health survey. Such an analysis should preferably be made by an outsider who is expert in the broad field of public health practice, for invariably such an individual sees things that are commonly overlooked. He inquires, inspects, investigates, and views with the eyes of the expert. His aid is invaluable, for his recommendations include new lines of endeavor, suggestions for the abandonment of old and useless practices, and still others that make for a more integrated and effective program. Every public health organization, no matter how expert and conscientious its personnel, will benefit from a thorough and scientific public health survey conducted at periodic intervals.

A general health survey has been defined as an investigation conducted by a trained corps of workers to determine the exact status of those conditions that may affect the health of a community directly or indirectly. Various methods are employed in assembling the facts on which the final recommendations are based. Some of the facts can be obtained from interviews and from a study of previous reports dealing with the health of the community. The value of such facts will depend on the person interviewed, his coöperation, his knowledge and grasp of the subject under consideration, and the effectiveness with which the interview is conducted. Similarly the available printed or typewritten reports on the health of the community will vary in quality and scope. On the other hand, reliable data can be assembled by the public health surveyor through sanitary inspections, statistical analyses, laboratory examinations, and other first hand methods. Such facts give the surveyor an insight into the local public health situation which enables him to be of real value to the community. His recommendations then are not based on hearsay evidence or on the doubtful observations of previous investigators, but rather on his own inspections and analyses. Viewing the situation with the eyes of the expert, alive to conditions that need alleviation or correction, the thoroughly informed surveyor is in a position to make a correct diagnosis of

public health work and to formulate a sound program for future activity which should serve as the chart and compass of the health department for years to come.

A public health survey is not only of value in planning a sound public health program and as a basis for effective health education, but it should serve as a means for apportioning wisely the available public health funds. In order for a public health survey to be most effective, it should be organized as a community project and in such a way that all the social, civic, religious, educational, welfare, scientific, business, and other worthy groups in the community will be interested. Adequate provision must be made for the right kind of publicity before the survey, during its progress, and after the final report has been submitted. In this way, the public health survey serves as a means of popular health education, and an enlightened community is highly essential for the introduction of an adequate public health program.

The development of the public health survey movement has been outlined earlier in this chapter in the discussion of the origin and evolution of the city health appraisal form. Today, upon request, the Committee on Administrative Health Practice of the American Public Health Association stands ready to send its trained workers into any community to appraise its health activities. As a result of the activities of this Committee, progressive and effective public health administration in the United States has been greatly stimulated. *The City Health Appraisal Form* is always employed in the surveys conducted by this Committee and while it is objective in character, and measures the quantity of work done, it is not always a good measure of quality. Usually, there is a high degree of correlation between the quantity and quality of health work but in some instances this is not the case. While the objective nature of any scientific method of analysis is highly desirable, it is probably true that in view of the inability of the *City Health Appraisal Form* to measure quality of health service, the subjective, unbiased opinion of the public health expert, rendered after a thorough knowledge and study of the facts, is a feature of the public health survey that should not be ignored. Its value as an instrument in promoting public health practice is too great for it to fall into disuse. The surveyor brings to his work a wealth of experience gained from observations made in various parts of the world as well as infor-

mation gleaned from his professional reading and training. He utilizes the various available laboratory aids to obtain a complete picture of the public health situation. By bringing to bear his professional experience and expert mind in the interpretation of his findings, he is in a position to advise the community on the conduct of its public health program so that it will be adequate in scope, economical in cost, and effective in its administration.

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